THE ENGINEER.

The Great Western Railway.

THE GREAT WESTERN RAILWAY.

THE total length of the Great Western Railway permanent way is probably about 1000 miles in excess of that of any other line in the United Kingdom. There are now open 1515½ miles of double, and 1430 miles of single line. On 54¼ miles there are three lines, and on 128½ miles there are four tracks. The total geographical length is 3128¼ miles. The number of independent lines now absorbed into and forming part of the Great Western system is as many as 115. The tonnage of merchandise and minerals carried during the year ending 30th June, 1909, was over 51 millions, and excluding season ticket holders the passengers carried exceeded in number 104 millions. We have here a colossal undertaking. Its successful operation is of the last importance to the whole south and west of England, yet for some obscure reason it has never attracted popular attention to the same extent as the London and North-Western Railway. It has hardly ever been written about. Nevertheless, it is certain that the Great Western Railway, its history, its progress, and its working, possess features of quite unparalleled interest for engineers, and, indeed, for all who are concerned with railways. The history of the line is inseparably connected with a man who takes rank with the greatest of the engineers who have made civilisation what it is to-day. Isambard Kingdom Brunel possessed a far greater intellect than George Stephenson. The latter was talented. Brunel, for better or for worse, was a genius. Stephenson was essentially a mechanical engineer. Brunel was a mechanical engineer and a civil engineer as well. Stephenson always ran in fetters. He went "canny." Brunel combined extreme caution with unmitigated audacity in the most original fashion. But Stephenson was always, and is still, the popular idol, because, by repute, he gave the world railways and the locomotive. Brunel did not originate that system of transport; but he developed the primary idea in a way all his own. The world will never again see a Brunel, because the modern engineer has not those demands made on his ingenuity or his resource which Brunel, and in a lesser degree George Stephenson, always met. A somewhat intimate acquaintance with the life history, the personal history that is to say, of both men is necessary to a right comprehension of the facts. Those who possess it require no proof of the truth of our statement. Those who do not it would be vain to attempt to convince.

The success attained by the Liverpool and Manchester Railway stimulated merchants in other trade centres to demand equal facilities for the conveyance of their goods from the place of manufacture to the place of sale or consumption. Bristol regarded itself as a port little inferior to Liverpool. That Liverpool held different views was natural. Bristol merchants were dependent on canals for the conveyance of merchandise to and from London. The service was intolerably slow. As far back as 1825 they attempted to get up a railway company. Nothing came of the attempt. The as yet incomplete Stockton and Darlington line, it is true, encouraged great expectations. Nicholas Wood, writing in 1832, said: "Public opinion was in an unsettled state as to the value of railways as an independent and distinct mechanical process for the purpose of general traffic, when the mania of 1825 brought every scheme alike, good, bad, and indifferent, before the public, and among the rest railways. The reaction and languor which succeeded that year of excitement involved railways in the general gloom of hostility produced against almost every scheme which had been agitated at that period; and few, if any, except the Liverpool and Manchester, were enabled to struggle through the mass of opposition induced by such feelings and the machinations of contending interests." It is not remarkable that this first proposal had an abortive ending. Nothing more was heard of the London and Bristol Railway for seven years. At last, in the autumn of 1832 a committee was formed of the members of the corporation and other public bodies to get a railway made to London. The first step was to select an engineer. Among the candidates for the post was Brunel, at the time only 27 years old. He was born on the 9th of April, 1806, at Portsmouth, and was the only son of Sir Marc Isambard Brunel, a most able engineer and a man of infinite ingenuity; it may be added that he was not knighted until 1841. Sir Marc was a native of Hacqueville, a little Norman town, where his family had lived for several generations. He served in the French navy, but being a Royalist, he had to quit France in 1793. He was made engineer to the State of New York. In 1799 he came to England, and in his thirtieth year married Miss Kingdom. He is best known to the present generation as the maker of the Thames Tunnel. He was the inventor of the first complete plant of wood-working machinery, which he devised for making pulley blocks for the ships of the British Navy. The plant consisted of forty-three separate machines. Where fifty men were employed in making the shells of the blocks he employed four, while six men did the work of sixty in making the sheaves. Drilling, slotting, and shaping machines, the excentric chuck, and the slide rest are all to be found in this machinery. He was little more than thirty when he completed this factory. The son of such a man, young Brunel enjoyed extraordinary advantages. He was one of his father's principal assistants in the construction of the Thames Tunnel. In 1829 he heard that designs were required for a suspension bridge over the Avon at Clifton, and became a competitor. Out of twenty-four plans his and three others were selected. Ultimately, after much change, Brunel's design was adopted, and he was appointed engineer to the undertaking. It will be seen that, young as he was, he had already a fine reputation. He obtained a majority of votes on the Selection Committee, and he was appointed engineer to the London and Bristol Railway. Hasty flying surveys of the country to be traversed were made; and the first public meeting was held on July 30th, 1833. Brunel refers to it in his diary: "Got through it very tolerably, which I consider great things. I hate public meetings. It is playing with a tiger, and all you can hope is that you may not get scratched or worse." Almost a month afterwards a company was formed, and the parliamentary survey commenced. Much time and labour were expended without avail, for money enough was not forthcoming to enable the directors to proceed in the parliamentary session of 1834, and for the moment the scheme fell through.

After many consultations it was decided that if the line from London to Bristol could not be made as a whole it might be made bit by bit; and accordingly the directors

Fig. 1—ENTRANCE TO PADDINGTON STATION, ABOUT 1850

went to Parliament for powers to make a line at one end from London to Reading, and at the other from Bristol to Bath. The first would be about 36 miles long; the second about 10 miles. The second reading of the Bill was carried on March 10th, 1834, and it was sent to committee April 16th. Then began the fight which attended every proposal for the construction of a railway in those days. Those interested in canals and stage coaches opposed because they feared competition. Land and house owners because they feared smoke and noise. Windsor opposed because the line did not run close to the town. Maidenhead because it went too close, and the traffic which paid toll on the bridge would be diverted to the railway. Farmers opposed it because they feared it would bring produce to London from a distance which would be cheaper than that which they supplied. The sittings in committee lasted 54 days. The expense was enormous. The Bill was passed and went to the House of Lords, where it was thrown out. In 1835 a new Bill was brought in. After renewed opposition it received the Royal Assent on the last day of August. It may be added that the Great Western Railway from London to Reading was constructed with few deviations from the route proposed in 1835. As first schemed it was intended that the line should have its terminus at Vauxhall. This was given up, and it was proposed that the Great Western and the London and Birmingham should have a terminus in common at Euston, a junction being effected at Kensal Green. The companies quarrelled about terms, and the idea was abandoned, and a terminus was built at Paddington, then open country. The history of the line during the next few years may be easily summarised. It was opened to Maidenhead, twenty-three miles, in 1838; to Twyford, eight miles further on, in July, 1839; from Twyford to Reading in March, 1840, and from Reading to Chippenham in May, 1841. At the other end the section from Bath to Bristol, 10 miles, was opened in August, 1840. The last link that joins Bath to Chippenham, 13 miles, was delayed by the construction of the Box tunnel, and was not opened until June the 30th, 1841. This completed the Great Western Railway for the time being. Of the numerous branches and lines absorbed mention has been made elsewhere. For the moment we must confine ourselves to the original line; in it the principal engineering interest centres.

We must revert now to Brunel, the young engineer, not yet thirty, who proposed to revolutionise railway construction, and very nearly succeeded. With a prescience which, as far as we can see, was not manifested by Stephenson, or, indeed, any other engineer, Brunel perceived that railways on a much larger scale than those contemplated in 1835-40 would be needed to meet the wants of the community. If you could travel fast, why not very fast? If it was a good thing to make 30 miles an hour by rail instead of 10 miles an hour by coach, it would be yet more excellent to run at 40 to 50 miles an hour. That the public would appreciate speed he did not for a moment doubt. But he also held that the 4ft. 8½in. gauge was too narrow for high speeds. He did not think it was safe, and he was certain that the engines must be too small, and particularly that the grates must be too narrow. He proposed, therefore, that the Great Western Railway should deserve the title. He would make it a big line, with big engines, big rolling stock, and high speeds. The gauge was, he held, the limiting factor, so he adopted a gauge of 7ft., and it is indisputable that the results attained justified his contentions in every respect.

In order to make this clear, it is necessary to consider the conditions obtaining at the time. The normal permanent way consisted of short rails supported on cubical stone blocks. It is true that these were being replaced with timber sleepers in many instances. None the less was the road bad. The idea of balancing loco-

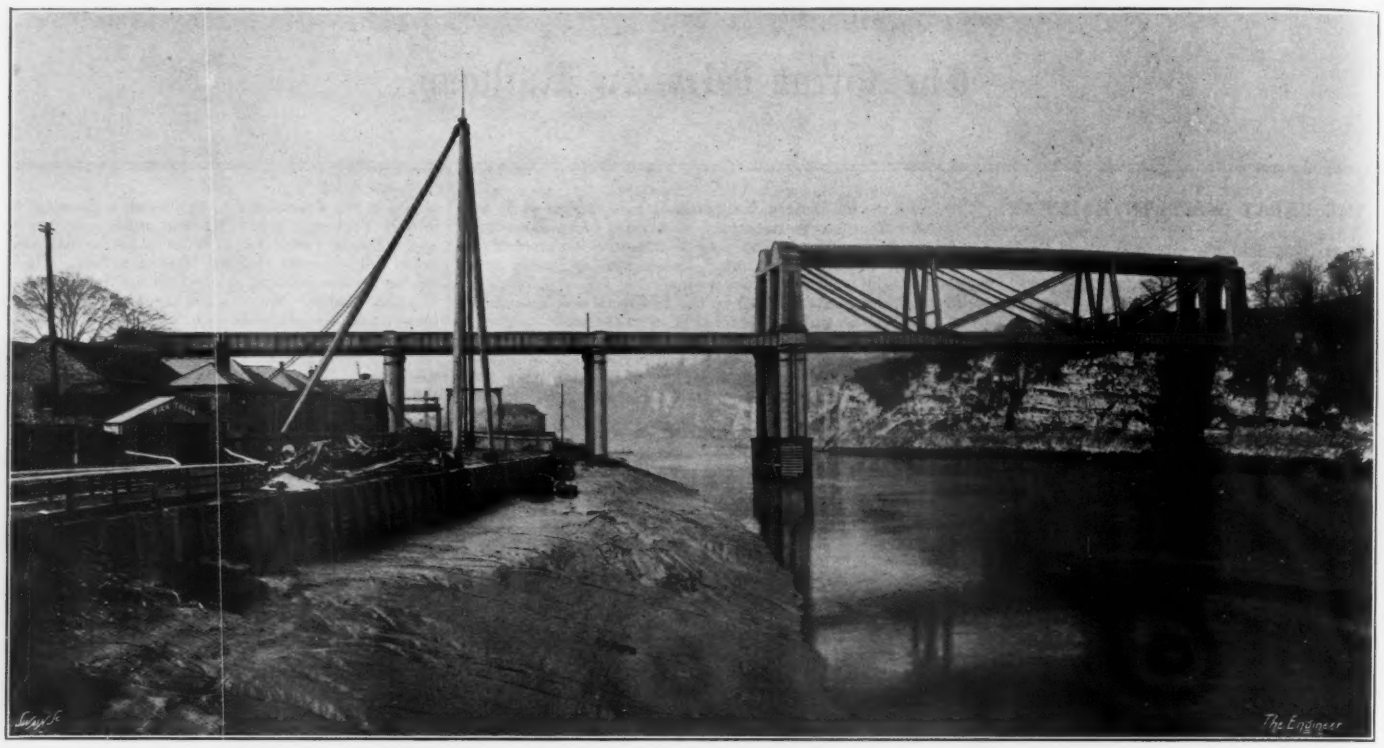


Fig. 2—THE CHEPSTOW BRIDGE

Fig. 3—ROYAL ALBERT BRIDGE, SALTASH

motives had not come into existence. It was held that at all costs the centre of gravity must be kept low, lest the engine should upset. There was small provision made for getting round curves. Obviously, the narrower the track the greater the risk. Again, with low, narrow engines it was held to be impossible to get steam enough for high speeds; and Stephenson introduced his long boiler locomotive to provide more heating surface. Even in these early days it was felt that the narrowness of the gauge cramped the railway. It does that at the present moment, although we have devised methods of getting over our troubles which were unknown in the first half of the last century. Brunel introduced another radical change—the ∩ rail with its flat feet bolted to longitudinal timber sleepers, braced apart yet tied to gauge by transverse transoms. The great defects of the system did not become apparent until the driving wheel loads got above five or six tons. Then the rails sank into the sleepers, and to prevent this it became necessary to interpose short lengths of thin hardwood boards, with the grain transverse to the rails, between the rails and the sleepers. In the beginning, however, it is beyond doubt that the running of trains on the Great Western was much more satisfactory to passengers, less noisy, smoother, and in every way better than anything on the London and Birmingham line. By increasing the gauge the chances of overturning were reduced to a minimum; and it is a noteworthy fact to which we shall have occasion to return, that while derailments were common on the narrow gauge, they were absolutely unknown on the Great Western Railway.

It must be clearly understood that proposals for the construction of many railways were before the public, and the question of gauge naturally arose. A contest began which culminated in the "Battle of the Gauges," which it is desirable to consider here, because, in the first place, it was inextricably mixed up with the history of the Great Western Railway; and secondly because it is full of engineering interest.

It was held by Brunel, and by a great many financiers and others, that it would be good policy for a railway to serve only a given district, and to have a monopoly in that district. After the opening of the Great Western line to Bristol, further extensions were planned to Exeter, Plymouth, Cornwall, Gloucester, Hereford, and South Wales, which were carried out. This practically gave the whole south-west of England and Wales over to the Great Western Company; while what is now the London and North-Western kept the Midlands and north-western parts of England and Wales. Between the two main lines, however, lay a great stretch of country unprovided for—a condition which could not last long, and in 1844 we find the two companies engaged in a hand-to-hand parliamentary fight for the right to serve this district. In 1844 the Great Western Company made a bid for the district referred to above, and promoted a Bill for an extension from Oxford to Rugby. Further, a broad gauge line was proposed from Oxford to Worcester, and thence to Kidderminster, Dudley, and Wolverhampton, in order to open up the Staffordshire and Worcestershire districts. Nor was the London and Birmingham Company idle. It also brought forward various proposals; and as was the custom at the time, all the proposals were referred to the Railway Department of the Board of Trade. Up to this time the question of the gauge had excited little animosity. The district system was, as we have said, in favour. That is to say, a company took a district, and it was not supposed that any other company could enter it. As we have said, the Great Western Company had the south-west of England and Wales to itself, just as the London and Birmingham and other lines had the Midlands. This was all very well so long as there were dozens of districts waiting for railways. The moment these happy conditions ceased to exist, companies began to encroach on each others preserves. So we find the Great Western trying to obtain a footing in the Black Country. Issue was joined over the question, where should break of gauge take place? The London and Birmingham advocated Oxford, which did not at all suit the Great Western, as that would put an end to the invasion of the Midlands. The Board of Trade held that the narrow gauge schemes north of Oxford were better than the broad gauge schemes. The whole question then went before Parliament, and after a tremendous contest the decision was given in favour of the Great Western lines. The Chairman of the Commons Committee stated that they had made up their minds without regard to the merits of the gauges, but because of the local merits of the two lines. Furthermore, the Great Western Company had to lay down a third rail so that narrow gauge stock could run without break of gauge.

Here Mr. Cobden interposed, and got a commission appointed to investigate the gauge question. The three Commissioners were Sir J. M. F. Smith, Mr. G. B. Airy, the Astronomer Royal, and Professor Barlow. As none of them seem to have had any experience in the working or management of railways, or any particular acquaintance with commerce, it may be presumed that they were impartial. It seems in the present day a curious selection. No fewer than forty-eight witnesses were examined, thirty-five absolutely narrow and only four broad gauge men, namely, Mr. C. A. Saunders, the secretary; Mr. Seymour Clarke, the traffic superintendent; Mr. Gooch, the locomotive superintendent; and Mr. Brunel.

A very long report resulted. The Commissioners stated the questions concerning which they proposed to hear evidence:—(1) Whether the break of gauge was an inconvenience of so much importance as to demand the interference of the Legislature; (2) what means could be adopted for obviating or mitigating such inconvenience;

Fig. 4—MAIDENHEAD BRIDGE

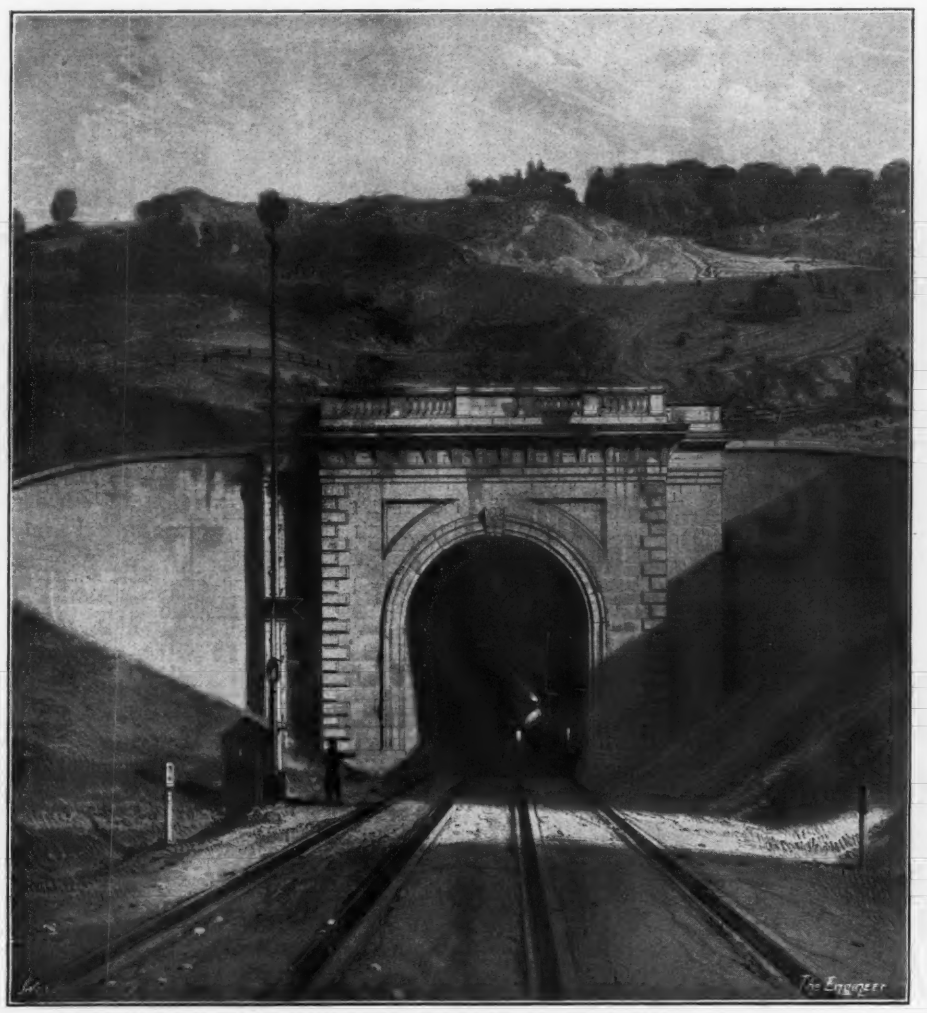


Fig. 5—ENTRANCE TO BOX TUNNEL

(3) considerations of the general policy of establishing a uniform gauge throughout the country. The contest excited an enormous amount of attention. The rival companies each ran trains to prove that its gauge was the best. The London and Birmingham Company maintained that its trains were as fast and as heavy as any broad gauge trains. The Commissioners arrived at four conclusions. The first was that, as regarded safety and comfort, one gauge was as safe as the other; the second, that although the broad gauge speeds were the higher, they were too fast for safety—at least, until the track was improved. The third, that the narrow gauge was best suited to the wants of the community; and, lastly, that the broad gauge made no adequate return for its increased cost.

The publication of the conclusions was followed by the issue of a flood of controversial literature. The "Battle of the Gauges" ranked in the public mind only second to Waterloo. Lying at the root of the popular excitement was the fact that these were the days of the railway mania, and it was held that the break of gauge question was got up simply as a cloak to a monopoly, which, indeed, it very probably was. Some of the arguments urged in favour of the broad gauge were curious. One was that the break of gauge was of no consequence, because through trains would be impracticable. A very interesting paper, containing fifty closely printed pages, and entitled "Observations on the Report of the Gauge Commissioners," was presented to Parliament. It was written by Brunel, Saunders and Gooch.

We reprint from this paper a letter and a report which possess great historical interest. We have a special reference to Stephenson's long boiler engine. The type of engine used by the Great Western Company is described on another page. The jumping and yawing were mainly due to the lack of balance and compensating weights, which were not thought of for several years subsequently, being first used by Daniel Kinear Clark on the South-Western Railway. Under the conditions the broad gauge engine ran much more steadily, and it is probable that the permanent way was much smoother and better than was any narrow gauge cross-sleeper road, to say nothing of rails laid on stone blocks.

LETTER ADDRESSED BY THE SECRETARY OF THE GREAT WESTERN RAILWAY COMPANY TO THE GAUGE COMMISSION.

Great Western Railway,
Paddington Terminus,
3rd January, 1846.

SIR,—Having returned on the 1st inst. to London, from York, where I had the honor to receive your Letter of the 30th ulto., I submitted it without delay to the Board of Directors of this Company, and am desired to express their entire concurrence in the arrangements then determined by the Gauge Commissioners to carry out fully and fairly the objects for which the experiments had been undertaken.

It is, however, a source of very great regret to this Board to learn, that after the utmost pains were taken to compress and adapt the experiments on the Broad Gauge to the views entertained, and the means said to be possessed by the Narrow Gauge Companies of making, without inconvenience, similar experiments, in order that they might be fairly contrasted with each other.—No such opportunity has yet been afforded, although the Directors have twice sent their officers into the North, according to previous appointments, to witness the performance of such experiments.

It must be within the recollection of the Commissioners, that the main purpose for which this Company contended, in suggesting a series of experiments, was to show the practical comparison in the means of working mixed Trains, *composed of second class as well as first class carriages*, at quick speed, travelling over a long line of Railway, with various gradients, and subject to the usual vicissitudes of wind and weather.

Mr. Brunel explained at the time that short single journies, upon chosen flat gradients, would not afford the same correct practical demonstration of the powers of Locomotive Engines, as applicable to such purposes,—that a much more fair result could be obtained from an average of the working of a Train over the long than over the short distance.

It was proposed by him to make three journies to Bristol and back, and the same number to Exeter and back, with train loads of 60, 70, and 80 tons, and against a similar distance, with the same loads, on any other Line, and afterwards to take one journey, at a fixed speed of 45 miles an hour, leaving each party to show what load they could carry at that rate.

It was only at the instigation of the Narrow Gauge party, and in consequence of their refusal to commit themselves at that time to any long distance, over varying gradients, that the trials were consented to be made upon 52 miles between London and Didcot, against 43 miles between York and Darlington, and a still shorter run between Manchester and Crewe.

I must premise that the Directors were led to express their wish that experiments should be made, not for any speculative theory, but to test the accuracy of evidence given—that the Narrow Gauge Lines had Engines capable of carrying as heavy loads, at as high a velocity as those on the Broad Gauge, with the same safety.

It was at the time a matter of notoriety, that all the Narrow Gauge Companies who were running quick trains, had limited them exclusively to *first class carriages*, and that the London and Birmingham Company, by public notice, had imposed a *restriction upon the number of first class passengers* to be taken on each Express Train, thus confining the public accommodation on the Narrow Gauge Lines to those only who could afford to pay the highest fare, and even depriving them of the certainty of performing the journey at all on one main thoroughfare to London, while from the commencement of the system introduced by the Great Western, they had carried both first and second class passengers in their quick Trains, without limitation as to the number of Railway Carriages of both classes in each Train.

It was also known to the Directors, that their rate of speed, with the heavier loads, was greater than on the other Lines—that the arrival of their Express Trains had been more punctual than on the other principal Line, and finally, that the work was accomplished on the Great Western by one Engine, while two Engines had been frequently employed on the Express Trains of the London and Birmingham Railway with the lighter loads.

Under these circumstances, presenting to the minds of the Directors most important features in the real question at issue, as to the capabilities of the Wide and Narrow Gauge, matters not merely affecting the Company, but of vast moment to the public, who are entitled to expect and will demand the very best system which can afford the greatest security, the quickest rate of travelling, made accessible not to one class only, but to all classes of passengers, unrestricted in number, to be conveyed so as to insure the journey to every person desirous of travelling by it; the experiments were urged by this Board, and undertaken to place the matter almost beyond the chance of further controversy.

They were fixed to be made on the Great Western, with four journies of 80, 70, 60, and 50 tons from Paddington to Didcot and back, for an average of the two trips, and the days were appointed. The first three were made; the heavier loads on a fine day with a high side wind acting in both directions on the trains, and the latter on an unfavourable day, with the rails extremely slippery from mist, obliging the driver to cut off some of the steam. Mr. Bidder, in the last journey, while at Didcot, expressed an objection to the next intended trip with 50 tons which was to have been performed on the same afternoon, observing that it was useless after showing the speed attained with 80, 70, and 60 ton loads.

He urged, however, that it should be done with 35 tons only, and finally arranged it at 40 tons, to which Mr. Brunel assented, although explaining that it would lead to no practical result as to power, as he should diminish the steam and not much increase the speed. It was then requested by some of the party that it might be postponed until after the Narrow Gauge experiments, for the convenience of those who wished to attend it.

The Directors have now received from Mr. Gooch, their Superintendent of the Locomotive Department, a report of what has since occurred in the course of the last fortnight, and while they deplore the casualty which has terminated for the present all chance of a fair comparison, they feel bound to call the special attention of the Commissioners as well as the public, to the facts recorded by Mr. Gooch, and confirmed to them, as far as he was present to witness them, by Mr. Brunel.

They are forcibly struck with the circumstance that the only real experiment yet made on the Narrow Gauge line, in the agreed manner, so as to admit of any comparison, was with 50 tons, while it was owing exclusively to Mr. Bidder's observations at Didcot that such trip was not made on the Great Western after it had been arranged for. The only comparison which seems to the Directors can yet be drawn from that single experiment is, that the Broad Gauge engine conveyed the 80 ton load with a high wind at the same speed that the Narrow Gauge engine took 50 tons only on a confessedly mild and favourable day.

But it is far more essential that no erroneous impressions should be allowed to pervade the public mind, from the very unfortunate accident on the Great North of England Railway, as to danger on quick trains with engines properly constructed. Not one instance has occurred of any Locomotive Engine on the Broad Gauge jumping off the rails, although daily travelling with express trains on the Great Western, even at speeds varying from 50 to 60 miles an hour. In the only accident which did occur to one of those trains, the carriages alone were thrown off in consequence of coming in contact with the iron troughs of a bridge, and then alighting on the rails laid on a peculiar system without ties between them, but the engine remained on the rails, and proceeded at once to Slough to procure assistance.

The accidents with the new Long Tubular Engines (recently made to rival the power of those Broad Gauge Engines which have been in use by this Company ever since 1840) by running off the rails without any known obstruction on the Line, may have a serious tendency to create apprehension of danger from speed unless the distinction and the real circumstances are properly described and known. The Directors under this conviction, with a deep sense of what is due to the public, and also to their own Proprietors, have resolved to publish Mr. Gooch's report.

I am desired now, in conclusion, to express to the Gauge Commissioners the earnest solicitation of the Directors that they will proceed with the prosecution of such safe and useful experiments as they may think necessary to elucidate any material facts, and *that they will also investigate minutely the accounts of cost and expense* on both systems for which this Company will be prepared to give the utmost facility.

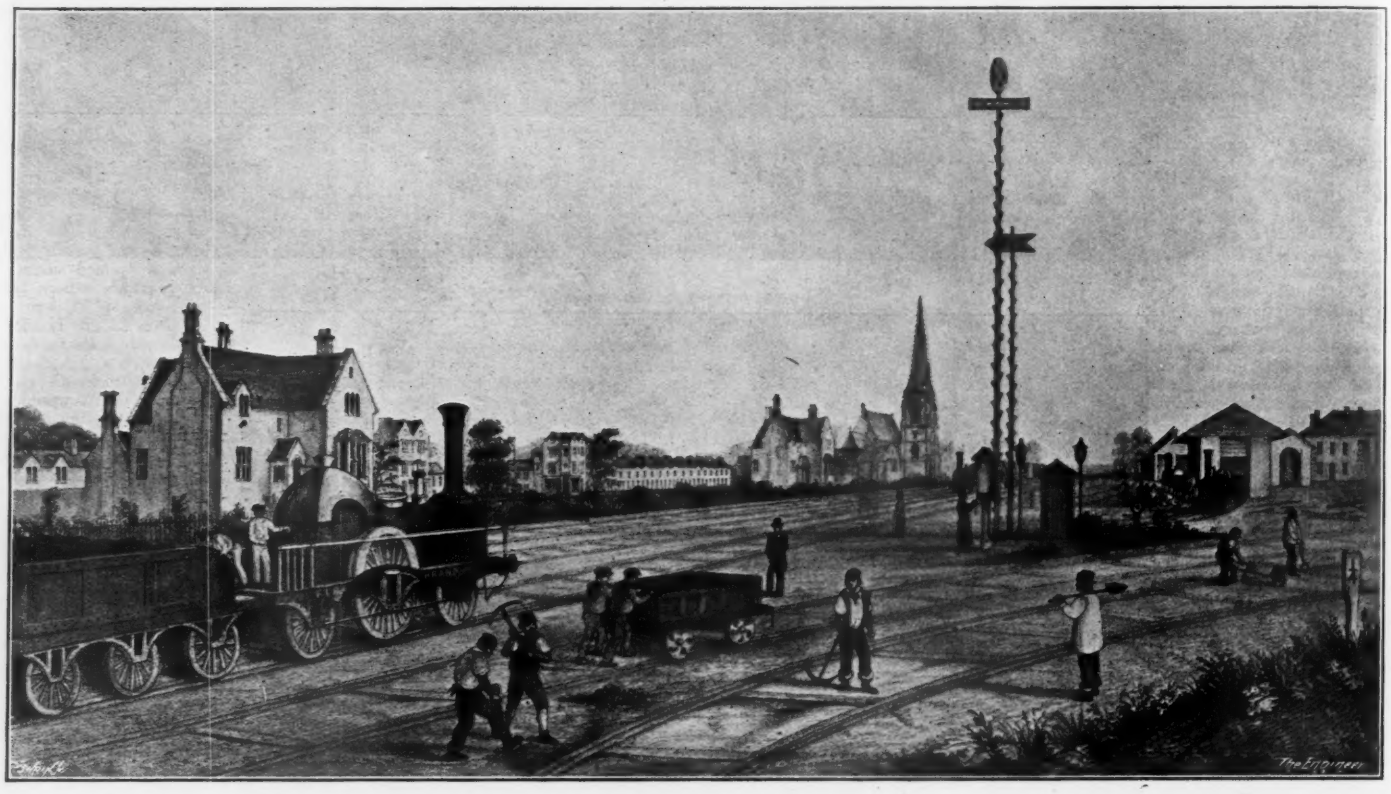


Fig. 6—SWINDON IN 1847

The experiments, with the heavy goods Trains, as well as with other Passenger Trains, may be made on any day most convenient to the Commissioners; and the Directors trust that the long journey to Exeter and back may be also made the subject of comparative experiment.

I remain, Sir,
Your very obedient Servant,
(Signed) C. A. SAUNDERS,
Secretary.

W. WATSON, Esq., Gauge Commission.

REPORT ADDRESSED BY MR. GOOCH TO THE DIRECTORS OF THE GREAT WESTERN RAILWAY COMPANY, AND TRANSMITTED TO THE GAUGE COMMISSIONERS, IN THE FOREGOING LETTER FROM MR. SAUNDERS.

Paddington, January 3rd, 1846.

GENTLEMEN,—In accordance with your directions, I went to Manchester last week for the purpose of witnessing the experiments to be made in the presence of the Gauge Commissioners on the line between Manchester and Crewe. Professor Barlow had also arrived, but after remaining there until the early part of the day on which the first trial was to have been made, we received an intimation that the experiments had been postponed by Mr. Bidder, on account of the probability of unfavourable weather, and also that he proposed to give up the experiments upon that line, and had determined to make them on the line between York and Darlington. I therefore went to York on the 28th, for the purpose of seeing the engines and carriages weighed, and other preparations made for the experiments on Tuesday.

I was, however, unable to do this, as the parties connected with the Narrow Gauge were occupied the whole day in making preliminary trials. We were unprepared on the Tuesday morning with the full load of 80 tons, which it had been arranged should be one of the first experiments tried, as corresponding with that made on the Great Western Railway, but there being a strong wind, Mr. Bidder determined to try an experiment with only 50 tons. This we did, and obtained only a very low average speed, in consequence of the wind; it was therefore arranged that the same experiment should be repeated on the following morning. The day (Wednesday) proved remarkably fine and moderately calm, and we obtained an average of 47·7 miles per hour. At this speed I found the engine exceedingly unsteady, so much so, that

I doubted the safety of it, and even deterred Mr. Brunel from returning upon it, which he had proposed to do. Professor Airy was upon the engine in the down trip. This engine, which being quite new, has as yet no name, stands very high, and has driving wheels of 6ft. 6in. in diameter; it has been built by Messrs. Stephenson since the commencement of the inquiry by the Gauge Commissioners, and has only been completed a few weeks. All the improvements of the day, and all the alterations suggested by Mr. Stephenson have been introduced, and every effort made to construct a powerful engine in as small a space and with as little weight as possible. Every contrivance has particularly been resorted to, to obtain the utmost width that the gauge is capable of giving. The cylinders are placed outside, and besides this a couple of additional inches have even been obtained by throwing the bosses and spokes of the wheels out of the centre of the tires; it may indeed safely be asserted, that in width everything has been done that could be done, and that the efforts to obtain width are apparent in every detail—while if I may judge by the yawing and pitching motion of the engine when moving at any velocity, much more has been done in increasing the length of the mass in proportion to the length of the base than is at all consistent with safety, notwithstanding that the front and back pair of wheels are as far apart as Mr. Stephenson has stated in his evidence before the Gauge Committee they could be safely and properly placed. After returning to York with the same load, that is, 49 tons 9 cwt. 2 qr., and upon its being strongly urged that the experiment with the 80 tons should be tried, it was, after considerable delay, so arranged. I should observe that on this as on each of the previous occasions every arrangement was made to profit by the smaller circumstances of advantage. Thus after getting the 80 tons train ready to start, and all the parties in the carriages, we were detained nearly half an hour to get the steam higher, and the water in the tender as hot as possible. We also passed the starting post at a speed of about 15 miles per hour, instead of stopping and starting from a state of rest, as in the corresponding experiment on the Great Western Railway. We also passed the arrival post at a speed of 39 miles per hour, instead of pulling up at in time to stop at it. At Darlington there is also an artificial blast worked by the stationary engine there, which was used for the purpose of blowing up the fire and heating the water in the tender during the time the engine was standing; a very excellent contrivance, which would have been of great use at Didcot, where, from the short time it was arranged for us to stop, to enable the two experiments to be made by daylight, we had only cold water and a black fire to start with: thus no artificial means were spared to produce the greatest possible effect, and this rendered it somewhat difficult to compare the results with those made on the Great Western Railway, where the trains were run at the hours fixed as for regular trains, and where no extraordinary means were used, making the experiment correspond with the ordinary working with this load of 80 tons. I had not an opportunity of weighing this train, but I believe the weight was ascertained by Mr. Cabry, and with a light breeze directly in our favour, we made an excellent run to Darlington, at an average speed of 44 miles per hour, *exclusive* of the time lost in starting and stopping, which for the reason before stated was not taken by me. Unfortunately this half experiment was not completed by at once returning, as we might have done, and so averaging the effect of the wind upon the speed of the engine, which from yesterday's result should have been something considerable, or in fact making it a similar experiment to the one tried on the Great Western Railway. We returned without making any experiment, and by another engine. As it was necessary for Mr. Brunel to return to town on Wednesday night, he arranged with Mr. Bidder, and with the approval of the Commissioners, before leaving, that a complete experiment or pair of trips, should be made with the 80 tons, the first thing on the following morning—on going to the Station, however, for this purpose I found that Mr. Bidder objected to try the experiment, on the ground that there was too much wind, *and had also changed the engine.* Professor Airy went out a mile or two on the Line to judge for himself, and did not consider that the wind was sufficiently strong to stop the experiment, and I feel quite certain there was not more wind, and certainly a very much clearer atmosphere than there was the day we made the experiment with 80 tons on the Great Western. Mr. Bidder, still declined to make the experiments, stating that if obliged to do so, he must be allowed twelve miles per hour for the effect of the wind, which was against him. If this calculation be correct, it would have reduced the average speed of a double trip, if it had been made the day before, when the wind blew in the other direction, to 38 miles per hour. Mr. Bidder now proposed to run a light train for the purpose of trying the evaporating power of the engine at high speeds—we started with five carriages and a North Midland engine, also of the long class, but with inside cylinders. None of the Commissioners or their Secretary, accompanied us. With this very light load, about 30 tons, we only attained the speed of about 45 to 46 miles per hour, until we came to the 21st mile, between which and the 22nd mile, and before I could take any further observation, the engine jumped off the rails, falling upon her side, taking the carriages with her, two of which were also thrown on their side. On examining the line immediately after the accident, the first place I noticed to be injured was a broken joint chair, and where the ends of the rails were bent, and the outer half of the chair forced away from the stone block. From the appearance of the rails and the clear evidence that it had been a heavy side blow from the engine that had caused the accident (it unfortunately having struck a weak place) I consider the excessive tendency to pitch and roll of the engine was the sole cause, and in this I am supported by my assistant, Mr. Martley, who was on the engine, and states that on the whole trip the side way or yawing motion had been very severe, and that he had observed the same the day before. I had also an opportunity some months ago of riding upon one of the same description of Engines on the Dover Railway, and then remarked the exceedingly unsafe motion when running at any speed. This I stated to the Commissioners in my evidence before them in October last, and the succession of accidents that have recently occurred with the engines built on this particular construction, in which everything has been strained to overcome the disadvantage of want of space, fully confirm the views I then expressed.

Shortly after the accident I returned to York and saw the Commissioners, who at once commenced a long and careful inquiry into the cause of the accident. Two of the parties who were on the engine at the time, stated that she ran very steadily. They were the Engineman and Mr. Winter, an assistant of Mr. Cabry, Engineer to the York and North Midland, while Mr. Martley, who has had considerable experience of the motion of a locomotive engine, at least on the Wide Gauge, having actually filled the place of Fireman on a Great Western engine for several months, for the purpose of acquiring practical information of their working, and made very numerous experiments for me at all speeds, distinctly states, that the rocking and yawing motion was fearful; this was also confirmed by an Engineman, a servant of the North of England Company, who was on the engine, and who stated to the Commissioners that he observed considerable rolling motion on the Embankments, and through the points at Thirsk Station, immediately after which the engine left the line and upset. In conclusion, the results of my observations on this line have confirmed me more fully in the views and opinions I have previously held and expressed—that to obtain practically even moderately high speed on the Narrow Gauge, with fair working loads, and taking the average of weather—the engines must be such a construction to obtain the requisite power, that they become excessively unsafe: by having so great a weight overhanging the wheels, both longitudinally and transversely from the extremely long boilers, and the outside cylinders, or, if inside cylinders be used, by the disproportionate height to which the whole must be raised—such engines cannot be otherwise than unsafe, even at moderate speed, on the Narrow Gauge, while on the Great Western, or Broad Gauge, from the weight being kept more compact, and entirely within the base, both longitudinally and transversely, the experience of many thousand miles per week run regularly during several years, at higher velocities than any attained in the experiments on the Narrow Gauge, proves them to be perfectly steady and safe—no accident having ever occurred on the Great Western Railway to an engine, that in any way resulted from speed—indeed, a mere sketch, such as the one I enclose, of an end view of the two engines, would lead anybody to draw the conclusion, that the one is too high and top heavy to be fit for high speeds, whilst the other has all the appearance of breadth and stability.

This accident may, I fear, now interfere with the progress of the experiments, and it is therefore much to be regretted, that notwithstanding the postponement of the first appointment and the number of days that have been devoted to the business on the Narrow Gauge lines, we have not yet obtained one complete experiment to match those made on the Great Western, and which, as I before observed, were made in a practical manner; as for working trains on the days, and starting punctually in both directions at the hours previously fixed, without reference to the weather, which on the first day happened to be windy, and on the second day was particularly unfavourable.

Since my return to London, I have been informed that many parts of the Line between York and the place at which we got off, show evidence of the extreme motion in the engine, many rails being bent and blocks fresh broken—particularly about the twelfth mile-post from York.

I am, Gentlemen,
Your very obedient Servant,
(Signed) D. GOOCH.

To the Directors of the Great Western Railway Company.

The stress laid on the character of the weather is almost grotesque in modern eyes. The unutterable contempt with which the unfortunate third-class passenger was regarded is extremely amusing when compared with the value attached to him in the present day. There is no doubt that the Great Western locomotives were at the time much more powerful than the London and Birmingham locomotives. No reply to Gooch's report was attempted.

In the long run the broad gauge was abandoned bit by bit. It does not appear, however, that the inconvenience of break of gauge was the principal reason. On the whole it seems that the cost of working and of the maintenance of the road was greater on the broad than on the narrow gauge by a very sensible amount; and engineers had learned that as regards high speeds and steadiness of running there was nothing to choose between the two. None the less is it to be regretted that the national gauge was not 5ft., or 5ft. 3in., as in Ireland. The wider gauge would have greatly facilitated the work of those who design locomotives.

We may now resume our sketch of the history of the Great Western Railway.

From what has already been said it will be gathered that the construction of the line presented few engineering difficulties. The country was level; the embankments were made out of the cuttings. All that portion of the railway between Paddington and Bristol is almost level. This result has been secured by concentrating the inclines. The summit is 270ft. above Paddington terminus, and 292ft. above Bristol station. The line rises gradually to Maidenhead, Reading, and Oxford, nowhere faster than at the rate of 1 in 1320. From the summit to Bath the line falls by two inclined planes—at Wootton Bassett and at Box. The gradients on these are 1 in 100, and at first the trains were always helped up them by pilots or pushers. The Wootton Bassett incline is 1 mile 550 yards long; that at Box 2 miles 660 yards, and on it is the Box tunnel, the first out of London. Thus, upon the whole line between Paddington and Bristol there are—

	Miles	yards.
Level, or not exceeding 4ft. to the mile ...	67	880
Above 4ft. and below 8ft. to the mile	47	110
Inclined planes	3	1210
Total length	118	440

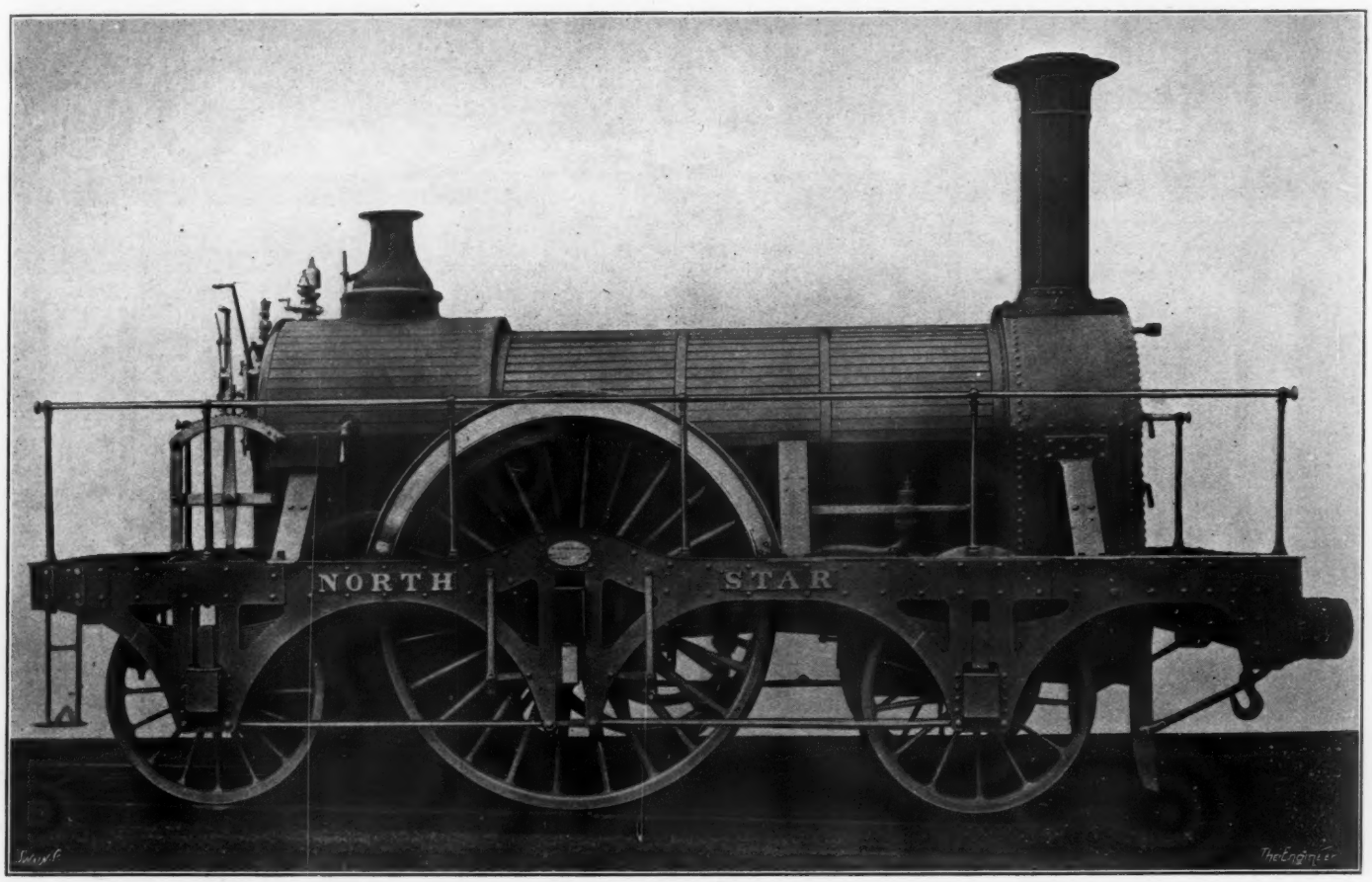


Fig. 7—THE NORTH STAR AS REBUILT, 1854

Four-fifths of the traffic were carried on an almost level line; a condition quite exceptional and existing on no other railway in the kingdom. The only really important works between Paddington and Bristol are the Box and Foxwood tunnels—Fig. 5 and Supplement. The first is 1¾ miles long, ventilated by six shafts each 30ft. in diameter. They vary in depth from 70ft. to 300ft. It was excavated plentiful, cheap and good, and Brunel took pleasure in making his bridges, tunnel ends, and stations ornamental. The entrance to the Box tunnel, of which we give an engraving—Fig. 5—may be cited as an example. A tunnel front near Bristol may be mentioned in particular. While it was being built a slip occurred behind it, rendering its completion unnecessary. It was left unfinished, and Much architectural effect could not be got. Brunel had the assistance of Sir M. Digby Wyatt, an eminent architect, in preparing the designs. The interior of the terminus is 700ft. long, divided in its width by two rows of columns into three spans, 68ft., 102ft., and 68ft., and is crossed by two transepts, 50ft. wide. The roof is of wrought iron arched ribs, covered partly with corrugated

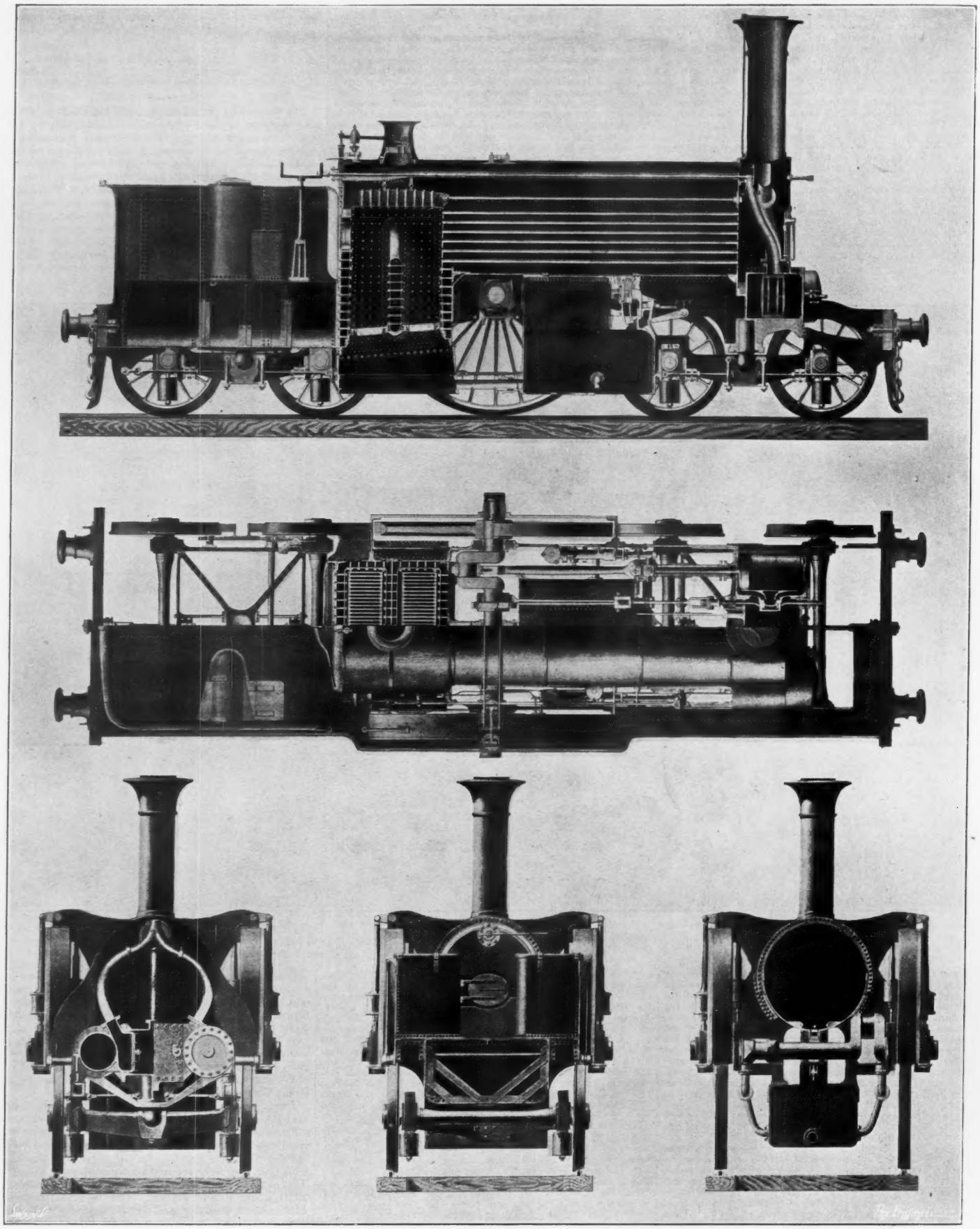


Fig. 8—BRISTOL AND EXETER TANK ENGINE, 1868

in fairly solid rock, and does not appear to have presented any special difficulties. The geologists of the period seem to have foretold disaster, and Brunel wrote an interesting letter to one of these gentlemen, in which he assured him that both he and his staff knew what they were about, and that there was really no risk. Brunel was right and the timorous geologists all wrong. Between Chippenham and Bristol building stone was planted with ivy, to give the appearance of a ruined gateway.

The permanent terminus at Paddington was not begun until 1849. It was completed for the time being in 1854. The temporary station, illustrated on page i., which preceded it, had the booking offices under the arches of Bishop's-road bridge. The railway enters Paddington through a cutting, and the station stands lower than the surrounding land. iron and partly with Paxton ridge-and-furrow glass. The columns are bolted down to heavy masses of concrete. The goods station, erected about the same time, is peculiarly interesting because of the large use made of hydraulic machinery, designed by William Armstrong—afterwards Lord Armstrong—who, in the course of a paper read before the British Association in 1854, said:—"I have also applied water pressure machinery extensively to

railway purposes, chiefly under the direction of Mr. Brunel, who has found a multitude of cases involving lifting or traction power in which it may be made available. Most of these applications are well exemplified at the new station of the Great Western Railway Company in London, where the loading and unloading of trucks, the hoisting into warehouses, the lifting of loaded trucks from one level to another, the moving of turntables, and the hauling of trucks and traversing machines are all performed, or about to be so, by means of hydraulic pressure supplied by one central steam engine with connected accumulators."

It is not necessary to go into any detail concerning the various additions to the Great Western Railway of minor importance. The line was opened to Exeter in 1844. Sir Daniel Gooch wrote in his diary: "On the 1st May this year the railway was opened through to Exeter. We had a special train with a large party from London to go down to the opening. A great dinner was given in the goods shed at Exeter station. I worked the train with the Actæon engine, one of our 7ft. class, with six carriages. We left London at 7.30 a.m. and arrived at Exeter at 12.30 p.m., having had some detention over the hour fixed. On the return journey we left Exeter at 5.20 p.m. and stopped at Paddington platform at 10.0. Sir Thomas Acland, who was with us, went at once to the House of Commons, and by 10.30 got up and told the House he had been in Exeter at 5.20, the distance 195 miles. It was a very hard day's work for me, as apart from driving the engine a distance of 390 miles, I had to be out early in the morning to see that all was right for our trip, and while at Exeter was busy with matters connected with the opening, so that my only chance of sitting down was for the hour we were at dinner. Next morning my back ached so that I could hardly walk." This was a very fine performance for the period, the speed being nearly 42 miles an hour including stops. When we remember that there was neither weatherboard or cab, we can appreciate what Gooch's day's work meant.

Between Taunton and Exeter there are long gradients of from 1 in 80 to 1 in 120. These have had a considerable influence on the design of Mr. Churchward's engines making long runs. We have not space to speak of the South Devon line, on which the atmospheric system was tried. On the Cornwall railway from Plymouth to Truro, and the West Cornwall extension from Truro to Penzance, occur many viaducts and the great Royal Albert Bridge. On the South Wales Railway from Grange Court to Milford Haven are the Chepstow bridge and the viaduct at Landore. Concerning the Cornwall railway, running through very difficult country, Brunel wrote:—"I must not be understood to argue against the advantage of straight lines or large and easy curves. But I wish to show that where small curves are unavoidable they can in practice be so constructed as not to be very prejudicial, and I consider that the character of the country in Cornwall is such that no railway can be constructed at any moderate expense without either sacrificing all consideration for the interests of localities and the position of the population to the mere choice of levels, or without steep gradients and sharp curves."

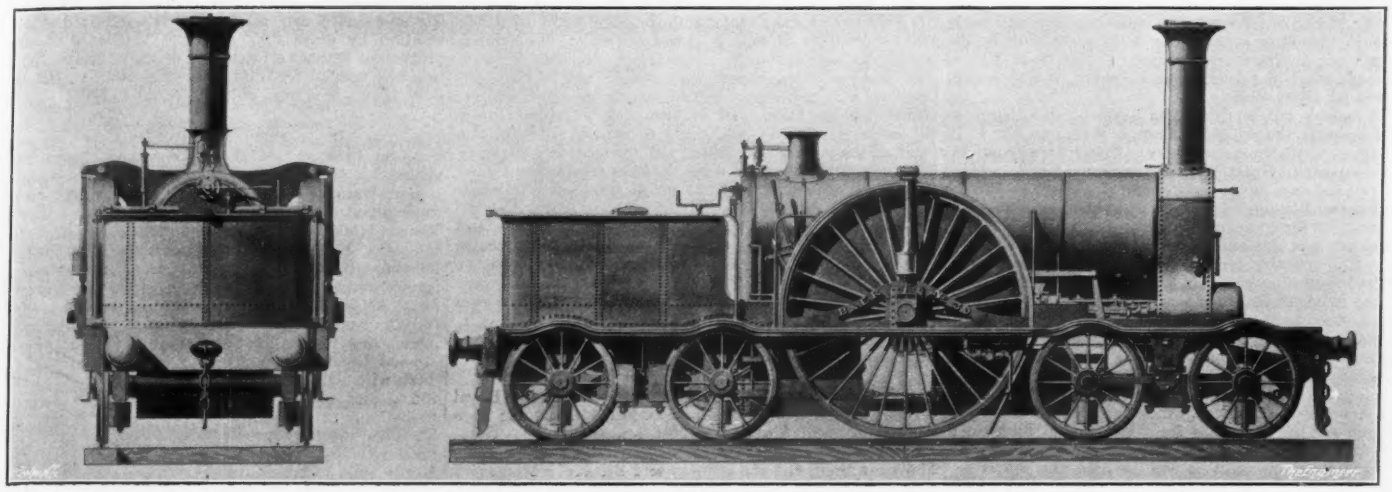


Fig. 9—BRISTOL AND EXETER TANK ENGINE, 1868

Nearly, if not all, the timber viaducts designed by Brunel have been replaced by steel or masonry structures. But none the less, they were remarkable for their size and originality of design. Thus the Landore Viaduct was 1760ft. long, with thirty-seven openings of various spans, one of 100ft., two of 73ft., two of 64ft., two of 50ft., and the rest about 40ft. The piers were some of stone, some of timber, some of masonry and timber. On the Cornwall railway no fewer than thirty-four valleys had to be crossed by viaducts, with an aggregate length of four miles on a line 60 miles long. Timber was used to save expense. The choice lay between it and iron, and the results were quite satisfactory so long as the weight of the engines remained moderate. The piers were plain walls built up to 35ft. below the rails; sometimes these piers were of great height. The St. Pinnock Viaduct, for example, was 153ft. above the bottom of the valley. The piers were 66ft. apart. The railway was supported on fan-shaped timber trusses, which took the thrust. The tension was taken by wrought iron ties.

It is to be noticed here that Brunel introduced what came many years afterwards to be called Palliser bolts. He held that the section at the bottom of a thread was much smaller than that of the body of the bolt and the rest so much waste iron; and he saw besides that the abrupt change at the commencement of the thread introduced another element of weakness. He therefore had the ends of the tie bars upset, and the screw threads were cut entirely "proud" of the bar. He retained full strength, and yet he was enabled to reduce the weight of the bar. It will be remembered that this device was patented by Captain Palliser for armour plate bolts; doubtless in complete ignorance of what Brunel had done years before.

Before proceeding to give detailed descriptions of the more interesting or important works carried out by Brunel, it is necessary to say something of the permanent way and the conditions under which the line was worked. Brunel held that the conditions of passenger traffic were such that the conditions of transit should be luxurious. The London and Birmingham Railway might be regarded as a business and commercial line. The Great Western was essentially aristocratic. Large numbers of first-class passengers travelled in those days in their private carriages, which were placed upon trucks; therefore the road must be as smooth as possible. Fig. 10 gives a cross section of the permanent way. It consisted of half timbers of American yellow pine, connected at intervals as shown by transoms. The main timbers were canted inwards at an inclination of 1 in 20, which is precisely the modern angle of cant, and tires are coned always to the same angle. Here we have a distinct survival of the fittest. The rails were rolled at Dowlais, Rhymney, and Ebbw Vale. They weighed about 60 lb. to the yard, rested on a strip of tarred felt, and were secured to the sleepers by screwed bolts.

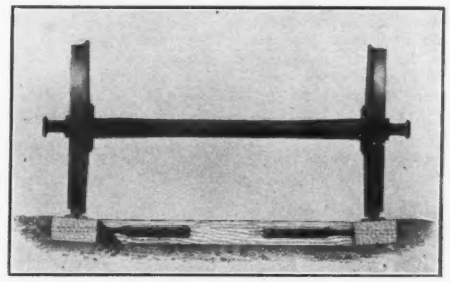


Fig. 10—G.W.R. PERMANENT WAY, ABOUT 1840

The width of the double road on embankments and under bridges was	30ft.
Made up of:—	
Double line 7ft. gauge	14ft.
Space between the two tracks	6ft.
Space outside each	2 × 5
Total	—— 30ft.
Width of cuttings	38ft. to 40ft.
Breadth of tunnels at rail level	30ft.
Height of ditto	25ft. to 30ft.
Minimum headway under overhead bridges...	16ft.

In Bourne's description of the railway, published in 1846

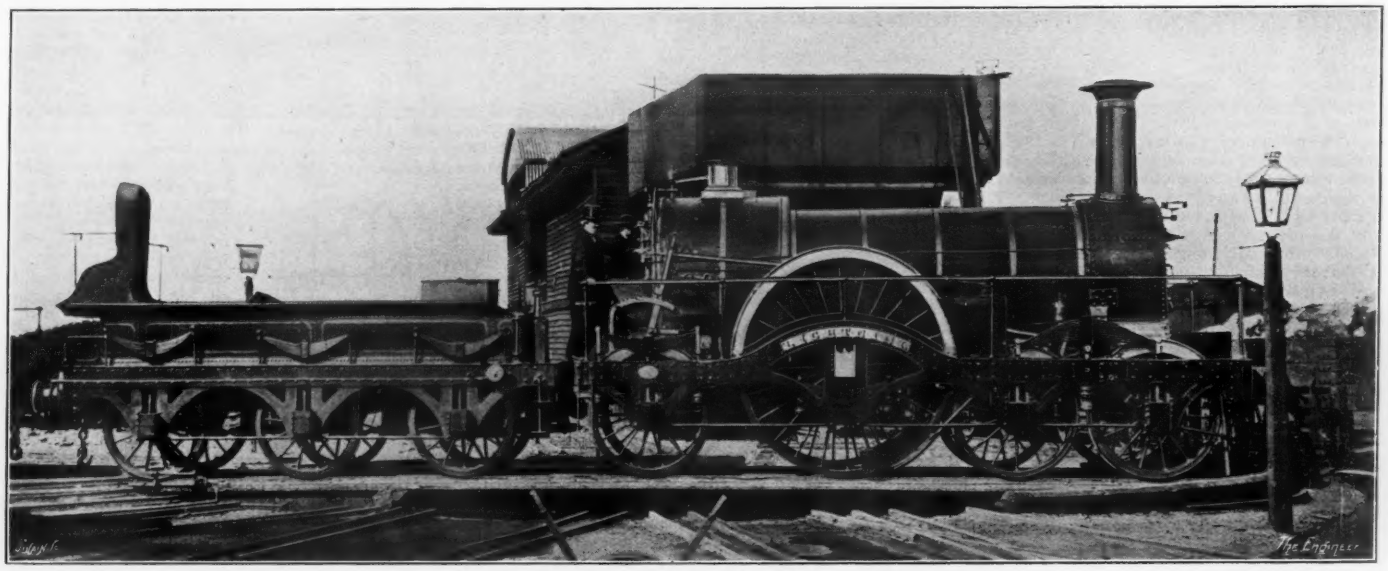


Fig. 11—THE LIGHTNING, ABOUT 1846

we read: "The stations upon the railway are in some respects peculiar. The great proportion of first-class intermediate traffic, and of persons travelling on the line with their private carriages, requires more attention to the general accommodation than is under other circumstances considered necessary. At the principal stations – see Art Supplement—of London, Slough, Reading, Swindon, Bath, and Bristol, the trains stand wholly under cover, and the stations themselves are roomy, and constructed with reference to the comfort of passengers of all classes who may be waiting at them, and are approached by broad roads. Both at these stations, and at those of the next class, and so including nearly the whole, arrangements are made for the addition or removal of private carriages and horse boxes to the train without the delay occasioned by the old methods." The transfer appears to have been effected by means of rolling bridges such as were in use in Paddington for many years.

Our readers will, we think, find it difficult to recognise in our illustration the site of Paddington Terminus, Fig. 1. In 1846 it was virtually open country. Under the original Act of Parliament the Great Western was denied direct access to London, and had, as we have stated elsewhere, to join the London and Birmingham at Kensal Green, and so on to Euston. But the company never acquiesced in the scheme, and access was obtained by a subsequent Act to Paddington. But months before the company entered into private negotiations with landowners, which were successful, and it began the construction of the road from Acton early in the spring of 1837, so that when the company got parliamentary sanction a few months later the terminal works were already far advanced; and so energetic were the contractors that they succeeded in finishing this portion of the line as soon as the section from Acton to Maidenhead, which had been already a year in hand, and the 22½ miles from Paddington to Maidenhead were opened in June, 1838; this was the extent of the company's line until July in the following year.

We have selected for one of our illustrations the beautiful bridge at Maidenhead—Fig. 4. It contains the two flattest and perhaps the largest arches ever made of bricks. The river Thames is here about 270ft. wide, with low banks, and in the middle is a shoal on which is founded the centre pier. Brunel intended to go down to the chalk, but borings proved that it was soft and overlaid by a bed of hard gravel conglomerate, and on this he built his piers. The main arches are semi-elliptical, each 128ft. span and 24ft. 3in. rise. They are flanked at each end by four semicircular arches, one of 21ft. span and three of 28ft. span. These are flood arches. The radius of curvature at the crowns of the main arches is 165ft., and the horizontal thrust at the keystones about

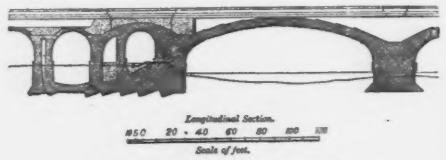


Fig. 12—MAIDENHEAD BRIDGE

10 tons per square foot. We give a section through one of the abutments, which shows the way in which the thrust is led down to the sawtooth lower course. Brunel first constructed landward flat arches. These he loaded with concrete. The centering of these was struck and an active thrust opposed to the main arches before their centers were struck. The bridge is beautiful in design, and has been perfectly successful.

In the Art Supplement we illustrate "The Engine-house" at Swindon as it existed in 1846. It was built some years before. The machinery was started in it in 1842, and it was put into regular use January 1st, 1843. Mr. Archibald Sturrock, subsequently locomotive superintendent of the Great Northern Railway, was works manager. It may be regarded as the beginning of the enormous establishment of the present day. Virtually this was a running shed. Nominally all the locomotives in it were either under steam or getting it up. Every train changed engines at Swindon, where each passenger train was delayed for 20 minutes, under a contract with a certain refreshment company. Swindon is 41¼ miles from Bristol, 33 miles from Cheltenham, and 39 from Gloucester. As a result of the system of working, more engines were kept at Swindon than at any other place. Accommodation was provided in the running shed for over fifty. It was a rectangular building, 490ft. by 72ft. The ends were open. The roof was of timber, slated, and provided with louvre ventilators. About the centre of its length, and abutting against it, was the engine-house proper. The engines stood at the sides, and were moved by a large central traverser, as shown in our engraving. The engine-house held thirty-six engines and tenders. At the northern end there were an erecting shop and a general repair shop.

We may add here, while speaking of engines, that those in use in 1846 weighed full about 19 tons. The weight of a first-class passenger coach seated for 32 was 7 tons 8 cwt., of a second-class to carry the same number 7 tons 5 cwt. Curiously, it was found that first-class passengers, with their baggage, went 14 to the ton, and second-class 15 to the ton. Whether the first-class passenger was bigger and fatter or carried more baggage than the second-class passenger there is no evidence to show. A comparison drawn between the London and Birmingham and the Great Western rolling stock is instructive and interesting:—

	Deadweight per passenger.
Great Western first-class, six wheels	518 lb.
L. and B.R. ,, four wheels	473 lb.
Great Western, second-class, six wheels	225 lb.
L. and B.R. ,, four wheels	238 lb.

We may compare these figures with those obtaining in the present day. Professor Dalby found in a particular boat special, consisting of two first-class saloons, one second and third class vehicle, one first-class dining car, one second and third-class dining car, one kitchen car, and two brake vans, seating accommodation was provided, exclusive of the dining cars, for 104 passengers, and the dead load to be hauled averaged 2.72 tons per passenger. Notwithstanding this increase in the dead load of luxurious accommodation, the fares are now less than in former days on corresponding services. We shall not be far out if we say that the deadweight of a modern express works out at 1.4 tons per seat, and under usual conditions probably at 2 tons per passenger.

The goods station at Bristol showep the advanced ideas of its designer. It was a rectangular building, 326ft. by 138ft., with three lines of rails disposed centrally. Two raised platforms were provided. Between the columns supporting the roof were placed very simple but efficient jib loading and unloading cranes, which commanded the trucks and the carts; and as each was within the range of the next, a heavy bale could be transferred from one end of the shed to the other. In the centre were three 32ft. turntables and a rolling platform connecting all the lines with each other. The level of the rails was below that of the main line, and the trucks were handled, as we have said elsewhere, by hydraulic power, the rise and fall being 12ft., traversed in thirty seconds. The central span of the roof was 60ft., the side spans 40ft., and the columns 35ft. apart. The design of the shed was very well thought out. It was convenient, and well arranged for the handling of goods.

CHEPSTOW BRIDGE.

The bridge over the Wye at Chepstow and the Royal Albert Bridge over the Tamar at Saltash, not far from Plymouth, are the two largest bridges on the Great Western system, and a remarkable parallel may be drawn between them and the Conway and Britannia bridges on the London and North-Western Railway. They may all be regarded as types, the only bridges of the kind in existence. They are all tubular, but there the likeness ceases, because the trains run through two of them and underneath the tubes of the other two.

At Chepstow Brunel found on the left bank a limestone precipice about 120ft. high, being the edge of a wide sweep of table land. On the right bank the ground rises from the level of the river slowly for a considerable distance. To keep a clear headway a long embankment carries the rails at this side; while a cutting, more than 21ft. deep, has been made in the cliff. The total space to be bridged is 600ft., and is divided into a river span of 300ft. and three land spans of 100ft. each, as will be seen from a recent photograph reproduced on page ii. On the left side there was, of course, an excellent foundation. On the right side the ground was treacherous to a degree, and after some experiments with large screw piles, which were unsuccessful because of boulders, Brunel determined to use cast iron cylinders, forced down by loading, and then filled with concrete—a simple operation in the present day, little known then. The work began in the spring of 1849. The piers in the land spans consist each of three cylinders, 6ft. in diameter, joined up in lengths of 7ft. The main pier is made up of a double row of cylinders, six in all, 8ft. in diameter, in lengths of 6ft. The bottom edges were sharp, and the cylinders were got down to the solid rock by very careful excavation, the water being kept down by pumping. No very serious difficulties were experienced until the central pier was begun, when much trouble was caused by boulders and large pieces of timber in the bed of the stream; one cylinder was cracked and was shored up until the obstacle was passed; a stout hoop was then placed inside it and the rock was safely reached.

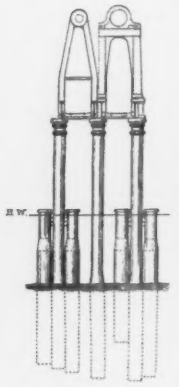


Fig. 13

After a time it was found that progress with the cylinders was so slow that the superstructure would be ready long before the piers, and to hasten the work Brunel adopted the pneumatic system. In the main piers four auxiliary 7ft. cylinders were sunk. These are braced to the large cylinders and greatly add to their stability. We give a sketch—Fig. 13—which will make the general arrangement clear. The bridge is for two lines of way, 7ft. gauge. Each road is carried on two longitudinal girders, 7½ft. deep; each girder has a triangular top flange, as shown in Fig. 14, with a plate iron vertical web and a slightly curved plate for the bottom flange. The land span girders are continuous throughout the total length of 300ft. Those across the river span are also continuous. The bridge proper consists of two horizontal cylindrical tubes, 9ft. in diameter, made of boiler plate ⅜in. and ⅝in. thick, stiffened at intervals by diaphragms. The tube is in compression, the horizontal girders being carried by suspension chains with links 20ft. long. There is one chain at each side of each road, or four in all. The chains carry the roadway girders at four points, and the tube is prevented from sagging by two struts which rest on the chains. To prevent distortion by a rolling load, diagonal stiffening chains are employed, as shown in our drawing, Fig 2. Each tube with its chains and trusses weighs 430 tons. This includes the longitudinal and cross girders, which weigh 130 tons. Tests made on the bank before erection showed that each truss would carry a distributed load of 770 tons, or 2¾ tons per foot run. The trusses were then taken asunder and preparations made for erecting them. This was done by floating them down the stream on pontoons. We have not space to describe the operation. The first floating took place on Thursday morning, April 8th, 1852, about 9 a.m., and by a quarter to 10 a.m. the tube was across the river. It was raised to its final position by crabs and chains. The work of erection progressed without a hitch, and on July the 4th, 1852, one line was opened for traffic, and the other on the 14th of July, 1852. The total cost was about £77,000.

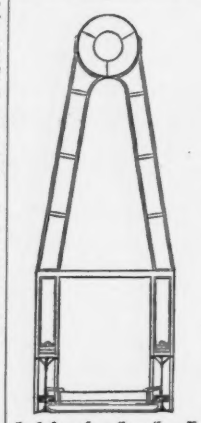


Fig. 14

SALTASH BRIDGE.

As far back as 1847 it was proposed that a railway should be carried from Cornwall into Plymouth. The scheme was one of many dozens of "wild cat" proposals made about the period of the railway mania. The river Tamar, 1100ft. wide and 80ft. deep at high water, stood in the way. Brunel suggested a steam ferry, but the scheme fell through until the following year, when a company was formed to construct the Cornwall railway, either with a ferry at Torpoint or a bridge at Saltash. Nothing further was done until 1847, when a few borings were made, and it was proposed that the river should be crossed by a timber viaduct with one span of 255ft. and six of 105ft. Something of the same kind had been proposed for the Chepstow Bridge. Here the Admiralty stepped in and insisted that there should be a clear headway of 100ft., two spans of 300ft. and two of 200ft. each. This would have required three piers in deep water. It was easier and cheaper to construct trusses than to sink piers, so Brunel decided to have only one deep-water pier and two main spans of 455ft. each. The result is the great Royal Albert Bridge, a structure familiar to all those who use the Great Western Railway coming from or going to Cornish towns.

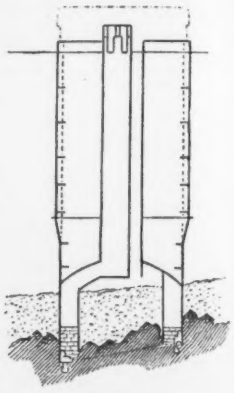


Fig. 15

The principal difficulty lay in getting in the foundation for the central pier. The Tamar is at Saltash an estuary rather than a river, with a rapid tideway and a rise and fall of many feet. We can do no more here than sketch with rapid pen the history of the construction of this more than remarkable bridge.

Brunel's first idea was to use a very large diving bell under which to work, by the aid of an air lock. But it was easily seen that it would come to the same thing if the caissons of the pier were themselves made to act as diving bells. In other words, he proposed to construct and sink a wrought iron cofferdam within which the pier masonry might be built up. Everything depended on whether the lower edge could be made so far water-tight that pumps could deal with the inevitable leakage. Now began operations which were unprecedented at that time, and still, we believe, remain unique. A cylinder was made of wrought iron 6ft. in diameter and 85ft. long. A timber platform and framing were placed on two old gun brig hulks secured side by side. The cylinder was up-ended in this framing, and dropped down endwise between the hulls. The whole was then towed to the site and the cylinder lowered. It seems to have been sufficiently tight in 16ft. or so of mud on the top of the rock to permit borings to be made within it. It was then raised and lowered again in another place. In all 175 borings were made, and a minute record obtained of the lie of the rock. In January, 1849, the water was pumped out of the cylinder, the mud excavated, and a few courses of masonry laid to demonstrate the practicability of the work.

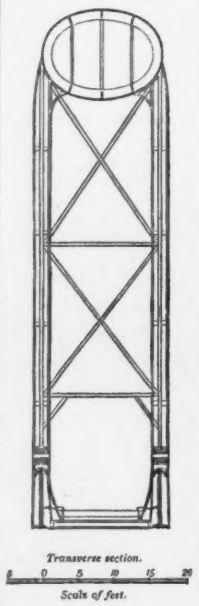


Fig. 16

Money here ran short, and nothing was done on the site for more than three years. During this period Brunel matured his plans. He decided not to make the bridge double. A single-line bridge would cost at least £100,000 less than a double-line bridge, and no inconvenience would be caused. "It is now universally admitted," wrote Brunel in a report to the Board of Trade in 1852, "that when a sufficient object is to be attained arrangements may easily be made by which a short piece of single line can be worked without any appreciable inconvenience," which is undoubtedly quite true. The designs were finished in 1852, and passed by the Admiralty some time in the following year; and in that year the work on the great central pier commenced.

A wrought iron caisson—Fig. 15—35ft. in diameter, was constructed. About 20ft. above the bottom a central dome was riveted, and from the centre rose a tube 10ft. in diameter. As it was intended to work under air pressure, it would have been extremely troublesome to keep the cylinder down. If the whole 30ft. dome had been used as a diving bell the floating effort when the tide was up would have been about 700 tons.

To avoid this Brunel placed another cylinder inside the bell, 27ft. in diameter, divided by vertical radial partitions into eleven compartments, and it was connected at the top to a 6ft. tube placed to one side of the 10ft. tube above mentioned, and on top of this tube was placed the air lock. In this way a ring of excavations 4ft. wide could be made all round the outer caisson, and pressure had to be maintained only in the annulus. In that part of the 10ft. pipe not occupied by the 6ft. tube were placed powerful pumps to keep down the water in the bell, and so reduce the pressure of air inside the annulus. The accompanying diagram—Fig. 15—from Brunel's life of his father, illustrates the arrangements. The cylinder, constructed on launching-ways on the bank, was moved down to low water and floated off with the rising tide. It was guided by four pontoons to its place, and sunk in June, 1854. In February, 1855, the cylinder was down to its final position, quite upright, and it rested everywhere on the rock, its bottom edge being 87ft. 6in. below high water. The rock bed in the annulus was dressed and filled with ashlar granite masonry, laid in blue lias hydraulic lime mortar. Space fails us. We can only say that the filling in of the pier with masonry proceeded. The inside ring was cut out; then the dome, and finally the outer cylinder was removed. At the end of 1856 the capstones were on, and the most difficult part of the work completed.

below, and that the Conway and Britannia tubes were lifted from the pontoons by hydraulic presses. At Saltash, docks were made under each end of the truss as it stood on the shore. Into these, pontoons were brought at low water. As the tide rose they took the truss off its bearings, and on September 1st, 1857, the floating into place began. The arrangements were in the hands of Captain Claxton, Mr. Brereton, Brunel's principal assistant, and Captain Harrison, commander of the Great Eastern. Mr. Brunel conducted all the operations from a stage erected on the top of the truss. The truss was floated into its place smoothly and without a hitch. The pontoons had water admitted. When they were clear they were withdrawn, and the work of lifting then began. The Britannia tubes were raised by a single huge hydraulic press at each end, standing on top of the pier, and coupled to the tubes by chains with links 6ft. long. This plan could not be used at Saltash, and three hydraulic presses were placed at each end under the girder, which was raised a few inches at a time, and built up to as fast as possible beneath. The rams of the presses had screw threads cut on the upper ends of them, and great nuts on these were kept screwed up tight as a precaution. No accident occurred, and the bridge—the total expenditure on which was only £225,000—was opened by Prince Albert on the 3rd of May, 1859. Mr. Brunel was away ill on the Continent at the time. On his return he paid a hurried visit to the Cornwall railway, and for the first and last time saw the result of an expenditure of mental, and, indeed, bodily labour, difficult in the present day to realise. He had to feel his way at every step. Matters of common knowledge now were still undiscovered; the difficulties of securing good workmanship—even large plates of uniform quality—were great. We are told that while preparing his

as the case may be, is by no means to be neglected in practice any more than in theory.

The Royal Albert Bridge was the last work Brunel did for the Great Western Railway Company. He died in 1859, of apoplexy, at the comparatively early age of 53, worn out by hard work and multifarious anxieties. The part that he played in extending steam navigation was of the highest possible importance. The Great Western, built in 1838, was the first regular Atlantic liner. The Great Britain was a wonderful achievement. She was built in 1848, and was the first ocean steamer propelled by a screw. The Great Eastern, begun in 1853, came before her time. The difficulties encountered in her construction were enormous as compared with those presented by, let us say, the Titanic or Olympic—vessels of 45,000 tons against the Great Eastern's 27,000 tons. In 1851 he designed the Hungerford suspension bridge, which stood where the Charing-cross railway bridge now spans the Thames. He designed the superb Clifton suspension bridge when he was only 23, but the design was not carried out until 1864, when the materials of the Hungerford bridge—removed in 1860—were utilised in its construction. He built docks at Monkwearmouth, Milford Haven, and Bristol as far back as 1831. In all that constitutes an engineer in the highest, fullest, and best sense, Brunel had no contemporary, no predecessor. If he has no successor, let it be remembered that, as we have already said, the conditions which call such men into being no longer have any existence. The way has been made smooth for the man of to-day.

The history of the Great Western Railway presents little engineering interest with one exception since Brunel died. It is a record of construction, absorption, extension. But there are no special features about these things deserving notice. The single exception is the construction

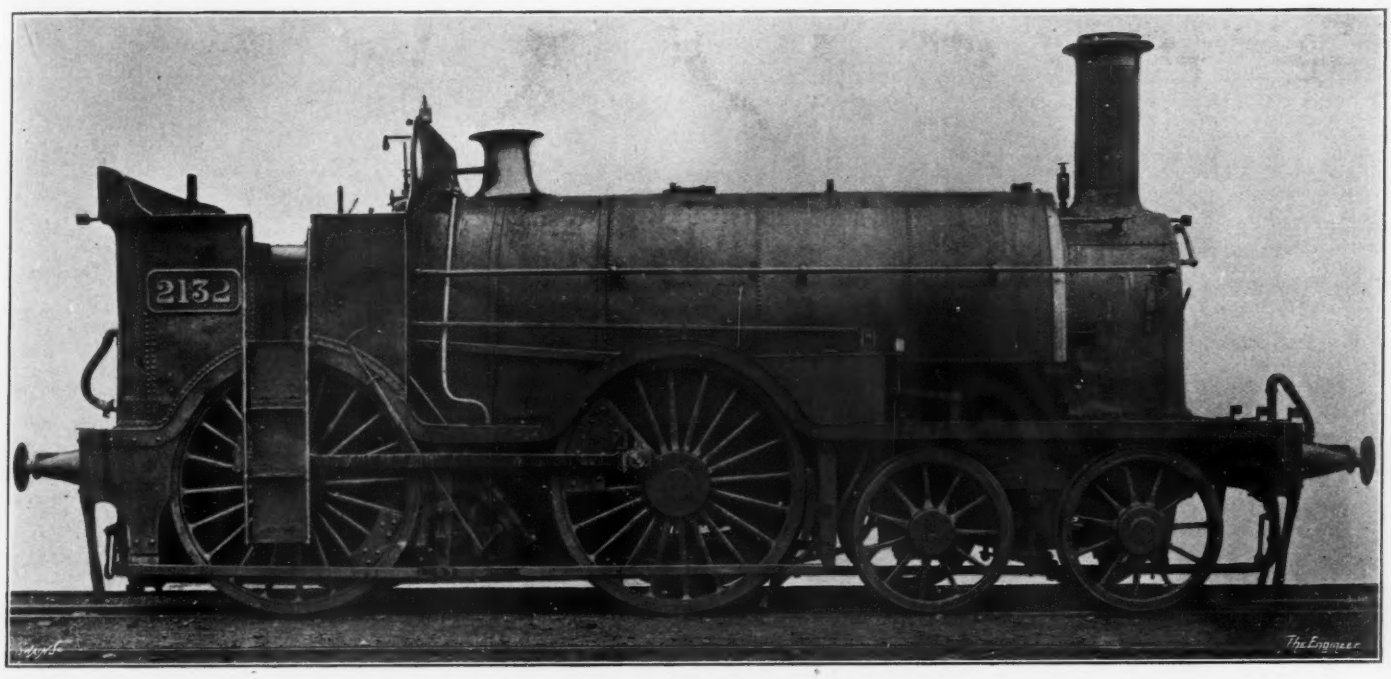


Fig. 17—OLD SOUTH DEVON TANK ENGINE

We come now to the superstructure. The whole length of the bridge, which is in part on a sharp curve, is nearly 2200ft., divided up among seventeen land spans from 70ft. to 90ft. wide, and the two river spans of 455ft. each. The rails are 190ft., and the highest part of the truss 260ft. above the lowest point of the foundations. The rails are carried throughout on horizontal girders. Those on the main spans are suspended from the trusses. The general idea involved is that of the Chepstow Bridge, namely, a tube to act as the strut in a bowstring girder, of which the "string" is a chain built up with links and pins. At Chepstow the top member or tube is horizontal; at Saltash it is arched. A portion of the chains had been made for the Clifton suspension bridge, Brunel's first design. Each truss—Fig. 16—consists of an oval wrought iron tube 16ft. 9in. wide by 12ft. 3in. deep, and approximately 460ft. long on the top. The truss is 56ft. deep in the centre. There is a suspension chain at each side of the tube. The versed sines of the tube and of the enforced catenary of the chains are the same. Eleven vertical struts are braced by diagonal ties. Each chain consists of two tiers of links, each tier formed of 14 and 15 links alternately. They are 7in. deep and 1in. thick. The total weight of the wrought ironwork in the superstructure of each span is 1060 tons. The trusses were made on the Devonshire side of the river, and when that for the western span was completed temporary piers were placed under each end, and a uniformly distributed load of 1190 tons placed on it. The deflection in the middle was only 5in. This comes out at 2.75 tons per foot run, in addition to the weight of the truss. The stress with a load of one ton per foot run, in addition to the weight of the truss flooring and ballast, is under four tons per square inch, giving a factor of safety of about five to one with the heaviest coal trains that can be put on the bridge.

The method adopted for raising the trusses was very ingenious. It will be remembered that the Chepstow truss was raised by crabs and chains from pontoons

diagrams for the Clifton suspension bridge, he had set his heart on getting links 20ft. long, with enlarged ends for eye-bolts, made without a weld, and he only succeeded after infinite trouble. In these present days we see much larger bridges made; but bearing all the conditions in mind, it may be said with safety that nothing exists, unless it be the Britannia Bridge, which demanded such a display of genius, engineering instinct, and audacity as the great structure which has for so many years carried heavy traffic across the Tamar.

Amongst several notable bridges of timber—a material in which Brunel worked with no less skill than in stone, brick, or iron—mention must be made of the beautiful timber and stone structure which crosses the Avon close to Bath, and which is shown in one of the pictures in the Art Supplement. This is a skew bridge with two openings, each 36ft. on the square, but, so great is the obliquity, no less than 89ft. on the skew. The arches are built up out of six ribs of curved Memel timber 6in. thick, each rib having five layers bolted together. These arches are parallel to the railway, and the thrusts at the haunches are partly supported by iron ties connecting the ends. The external spandrels are filled in with ornamental cast ironwork and the inner spandrels with cross ties and braces.

Before concluding these brief notes on a few of Brunel's bridges, we must quote from a letter he addressed in December, 1854, to one of his pupils. It will be found in his Life, written by his son, p. 178:—

> Let me give you one general piece of advice—that while in all works you endeavour to employ the materials used in the most economical manner, and to avoid waste, yet always put rather an excess of material in quantity. . . . Consider all structures and all bodies, and all materials of foundations, to be made of very elastic india-rubber, and proportion them so that they will stand and keep their shape; you will by those means diminish greatly the required thickness; *then add 50 per cent.* . . . I have found that there is not a single substance we have to deal with, from cast iron to clay, which should not practically be treated strictly as a yielding elastic substance, and that the amount of compression or tension,

of the Severn Tunnel, and to a brief account of that we shall devote our remaining space.

The river Severn separates England from South Wales. The old mail coach road ran to a place called New Passage on one side. The crossing was effected by a ferry, and coaches were taken up again at Portskewet. The water distance traversed was about 2¼ miles; the river being here really an estuary, up and down which tremendous tides ran, the rise and fall being as much as 40ft., and the velocity over 10 knots. Subsequently, the South Wales Union railway was made connecting Bristol and Gloucester. It runs in Wales along the right bank of the Severn. It is on this line that the Chepstow bridge crosses the Wye, not far from its junction with the Severn. The English portion of this line runs from Bristol to New Passage. When it was made wooden piers were built at each side, and between these a steam ferryboat plied. The inconvenience was great, and various schemes were proposed for surmounting the difficulty. At last two definite plans were laid before Parliament—one for a bridge, the other for a tunnel; and in 1872 Parliament sanctioned a tunnel, and the works began in 1873. Shafts were sunk on shore, and drift ways were driven. In this work few difficulties were encountered, and the union of heading had been nearly effected under the river when a land spring was tapped, and the works drowned.

In order that what happened may be understood, it is necessary to explain that the total length of the work is made up of approach cuttings in the shore, land tunnels, and the portion under the river. The total length is as near as may be 7 miles; of this 4¼ miles are tunnels. Under the deepest part of the estuary the line is level for 12 chains; it then rises with a gradient of 1 in 100 towards the English, and 1 in 90 towards the Welsh end. The tunnel has a semi-circular top, with a radius of 13ft. and curved side walls and invert. It was close to Sudbrook shaft, on the Welsh side and on land, that the spring burst in on the 16th of October, 1879. Sir J. Hawkshaw, who had previously been consulting engineer

was now appointed engineer-in-chief with Mr. Richardson, and the contract for the construction of the tunnel was given to Mr. T. A. Walker. The story of the attempts made to deal with the inburst of water is too long to be re-told here. The entrance of water had been anticipated, and doors were provided to stop the drift ways. These were open at the time. The men in the workings fled for their lives. The pumps were quite overpowered. Nothing could be done till a door was closed. This was 350 yards from the shaft, along the drift way under the Severn. Divers tried to get through to it, but could not succeed, because they could not drag their hose with them. Then one man named Lambert, with a courage and pertinacity worthy of all praise, volunteered to go down with a Fleuss apparatus. After being below for an hour and twenty minutes, he relieved the anxiety of those above by returning. He had been successful. Nothing, however, was done to get rid of the water until May the 30th, 1883, when a new pumping shaft had been sunk at Sudbrook, in which three pumps were put to work. The water was rapidly lowered, and a new drift was driven below the old one. All went well until a point about 100 yards from that at which the water first burst in was reached. Then the works were again flooded. Once more Lambert came to the rescue, and the inrush was stayed by closing a door. Meanwhile the work proceeded at the other end of the tunnel. Then leakage b gan to find its way in through the river bed. A great hole was stopped with bags full of puddle clay; but it became evident that whether the tunnel could be made or not was a question of pumping, and finally we find the greatest installation of pumps ever heard of at work. In September, 1884, there were no fewer than nineteen doing all they were able to do, and most of these of great size, as, for example, five Cornish engines, with 70in. cylinders, 10ft. stroke. The total quantity they raised was 46,000 gallons, or nearly 206 tons, per minute. In this way the water was kept down and the work proceeded. The brickwork is 2ft. 3in. thick, except in places under the river, where it is 3ft. in the arch and side walls. The bricks are all vitrified. In one week as much as 2000 cubic yards, or 600,000 bricks, have been laid in mortar, one part Portland cement and two parts sand. The greatest amount of excavation done in tunnelling was about 6000 cubic yards in a week. There were in all seven shafts, some for pumping, some for winding. The excavation was mainly accomplished with compressed air rock drills and blasting. The ventilation was maintained by the air from the drills and by a fan at Sudbrook. 18ft. in diameter and 7ft. wide. The works were lighted by arc lamps.

We have not mentioned minor difficulties and hindrances that cropped up. The tunnel was at last completed, after thirteen years of labour. It was opened, in the sense that an official train passed through it on September 6th, 1885. The train consisted of an engine and two saloon carriages. The trip was made in half an hour, "caution (apparently) marking the guarded way," and not long afterwards the line was opened for general traffic. The Severn Tunnel is by far the longest in Great Britain. The difficulties met with in its construction were special, and in certain ways unique. The leakage through the river bottom was insignificant as compared with that of the so-called land spring, which was really supplied by small rivers on the surface, as well as by subterranean waters. Its construction was marked by several heroic acts, but by none more praiseworthy than that of the diver Lambert. The tunnel has done all that was expected, and more in the way of facilitating traffic. Toward the end the pumps had to lift 23 millions of gallons per day, and now the tunnel is drained by six Cornish beam engines, with 70in. cylinders, lifting 75 millions of gallons per week. 76,000,000 of bricks and 37,000 tons of cement were used in its construction, and the average number of men employed was 3600.

We cannot conclude our historical notice of the Great Western Railway without a reference to Fishguard. A little place at the mouth of the river Gwayne, we believe it was intended that this was to have been the terminus of the South Wales line in 1844. For many years communication was maintained with Ireland by the company's steamers running between New Milford and Waterford. In the present day the boats ply between Fishguard and Rosslare, on the Irish coast, not far from Wexford. A very fine breakwater—page xxiv.—has there been constructed. Turbine steamers are used—the St. Andrew, St. George, St. David, and St. Patrick, with a speed of 23 knots. A very complete description of the works was given in our issues for December 3rd and 10th, 1909.

We have to express our indebtedness to Mr. A. G. Smith, of the Engineer's Department at Paddington, for valuable assistance in the preparation of this historical notice. Several of our illustrations are taken from a very beautiful folio by Bourne, published in 1846.

THE LOCOMOTIVES OF THE GREAT WESTERN RAILWAY.

In tracing the history of the rolling stock of the Great Western Railway for the past seventy years, one cannot help expressing regret that the load gauge of the year 1840 does not exist in 1910. The possibilities it would present by allowing increased cross-sectional dimensions would relieve every railway engineer of much anxiety in dealing with modern heavy traffic. These possibilities can readily be appreciated by comparison of the broad gauge load gauge and that in use at the present time—Fig. 19.

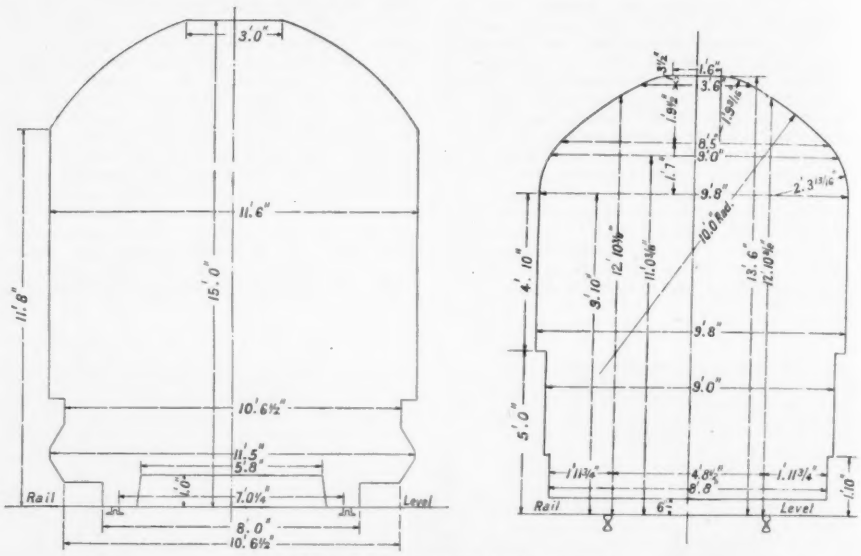


Fig. 19—BROAD AND NARROW LOAD GAUGES

The main line from London was commenced in 1835, and gradually creeping west, was opened between London and Bristol on the "Broad" gauge of 7ft. 0¼in. in 1840. Previously to 1840 the line had been worked by thirty-six engines—twenty with 7ft. driving wheels and sixteen with 9ft. driving wheels—built to their own drawings by different locomotive builders in Liverpool, Manchester, and Newcastle. As was to be expected, the engines varied considerably in design and dimensions. Mr. (afterwards Sir Daniel) Gooch, the locomotive superintendent, calls the North Star the most powerful and reliable of these early engines. The illustration—Fig. 7—shows the engine as altered. As originally built in 1837 by Stephenson and Co., of Newcastle, she had cylinders 15in. diameter by 18in. stroke, and was fitted with the old "Gab" motion—Fig. 20. The boiler had a dome on the barrel and two separate safety valves—one locked and one spring-loaded on the barrel. About the year 1854 the boiler was lengthened about 5in., the dome removed entirely, and the safety valves combined and placed together on the existing manhole on the fire-box. In this condition Gooch expansion gear was also fitted, and the cylinders were enlarged. The engine worked until the year 1870, and covered a total mileage of 429,000. The principal dimensions were as follows:—

Cylinders	16in. dia. by 18in. stroke
Driving wheels	7ft. dia.
Leading and trailing wheels	4ft. dia.
Heating surface—	
Tubes	654.7 sq. ft.
Fire-box	70.1 sq. ft.
Total	724.8 sq. ft.
Grate area	13 sq. ft.
Boiler pressure	100 lb. per square inch

There were twelve engines in the original "Star" class, with names as follows:—

North Star
Morning Star
Evening Star
Dog Star
Polar Star
Red Star
Lode Star
Rising Star
Bright Star
Shooting Star
Royal Star
Western Star

All these were made by Messrs. Stephenson, of Newcastle, and delivered between 1838 and 1841. The design of the boiler varied in different engines, as shown by the illustrations on page xx.

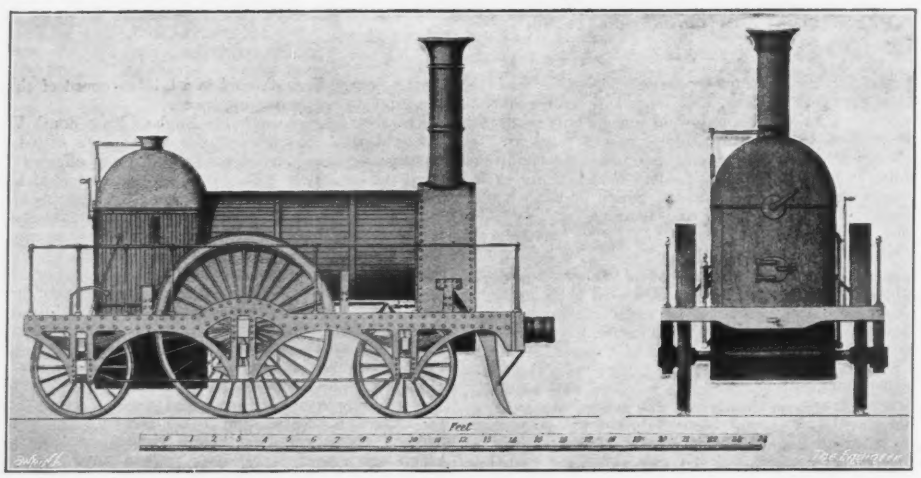


Fig. 18—THE IXION

As a matter of interest, we reproduce the invoice of the original Polar Star, dated June 8th, 1840—Fig. 21. Eleven of the above names have been given to four-cylinder 4–6–0 engines built in 1907, and Mr. Churchward has added a constellation by the production of the Great Bear, a woodcut of which we produce in our large Supplement.

In the pioneer days of steam locomotion the training of the drivers and firemen played an important part. The greater portion of this work was undertaken by Mr. Gooch, and the perusal of the earliest "Black Book" at Swindon, in which the peccadilloes of the men and the discipline applied shows that it was written by himself. We cull a few extracts from this book, as illustrating some of the offences.

September 4th, 1840. J. H.—For running his engine in a careless manner when pumping water upon the main line, and striking the "Wild Fire" engine so as to break her frame end, and considerably injured his own tender.—Fined 10s.

The early engines were fitted with water pumps, which were actuated from one of the axles, and the boiler consequently could not be fed when the engine was standing, and had to be run up and down the line. To overcome this difficulty later engines were either fitted with hand pumps or with donkey pumps with a separate cylinder.

February 12th, 1841. *Engineman R———*. A parcel containing a flute having been lost on Christmas Day, it was traced about the end of January to have been in the possession of R———, who had kept it during the whole of this time. The gentleman who lost it was put to the expense of £4 4s. in searching for it, which R——— has been ordered to pay.

It is not stated that R——— played the flute, but presumably it was used in the Christmas festivities.

November 8th, 1841. *Engineman B———*. When running the up mail train at night his piston failed at Bath, and he, without ascertaining the cause or seeing what was the matter with his engine, disconnected the other piston and rendered his engine perfectly useless. It detained the engine a long time until the bank engine could be brought to his assistance.—Fined 10s. and suspended two days.

May 5th, 1842. *Engineman T———*. Reported by a passenger for walking along the steps of the carriages to the guards during the time the train was in motion, and drinking some beer with them.—The case was brought before the directors, who fined the conductor very heavily, dismissed the guards and fined T——— 20s.

August 2nd, 1845. *Engineman B———*. On two occasions within the last fortnight he has stopped the mail train by neglecting his pumps, and having his fire to pull out in both cases. When the pumps were examined they were found in good order. He has also become generally careless, and I fear is getting into drunken habits.—Discharged.

We produce a copy of the time-table of July, 1840—Fig. 22—announcing the extension of the line to Faringdon Road—now named Challow—"for the conveyance of passengers, carriages, horses, goods, and parcels." Rates

are quoted for the conveyance of carriages, horses, and for the hire of post-horses to "bring carriages from any part of London to the station at Paddington," these to "include post-boys." First-class passengers were accommodated in closed carriages, second-class in open carriages, and third-class passengers travelled by goods trains only, in uncovered trucks, and 14 lb. of luggage was allowed each passenger.

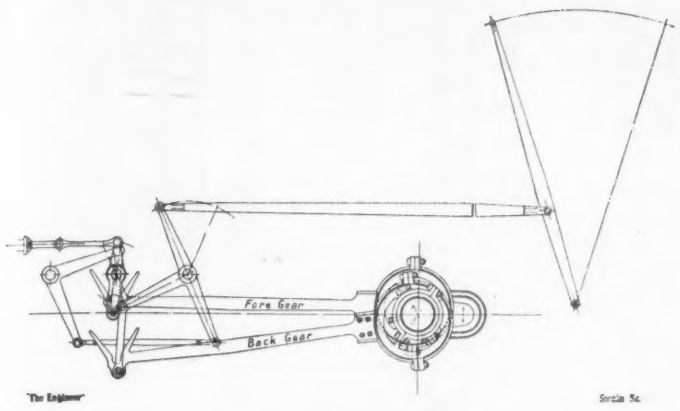


Fig. 20—GAB REVERSING GEAR

Soon after his appointment as locomotive superintendent in 1837 Mr. Gooch prepared designs for engines, 142 of which were ordered from different makers, the first of them, the Firefly, being delivered in 1840. Swindon was decided on in this year as the site for the locomotive, carriage and wagon works, and we reproduce a view of Swindon in 1847 which shows the Firebrand, a sister engine to the Firefly—Fig. 6. Great Western men will readily recognise the running shed on the right of the picture, an interior view of which, reproduced from Bourne's splendid work, appears in one of our Supplements. Originally the side of the roof facing the line was supported on pillars. Later this was boarded in, and the shop exists in this form at the present day, being used for repairs.

Below we produce a copy of the valve card taken from the North Star in 1854 when fitted with the "Gab" motion:—

Outside lap	$\frac{3}{4}$in.	Steam ports ...	11in. by $1\frac{1}{2}$in.
Inside lap	$\frac{1}{16}$in.	Exhaust ports...	11in. by $2\frac{3}{4}$in.
Cylinders	16in. by 18in.	Blast pipe top... ...	4in. dia.
Travel of valve	$3\frac{3}{4}$in.	Lead...	$\frac{3}{32}$in.

Steam cut off.		Exhaust opens.		Compression begins.		Valve opens.	
Front stroke.	Back stroke.	Front stroke.	Back stroke.	Front stroke.	Back stroke.	Front stroke.	Back stroke.
in. $13\frac{7}{8}$	in. $13\frac{1}{8}$	in. $16\frac{1}{4}$	in. $16\frac{9}{16}$	in. $16\frac{1}{4}$	in. $15\frac{7}{8}$	in. $1\frac{1}{8}$	in. $1\frac{1}{8}$

Ixion, Fig. 18, a similar engine to the North Star, was used by Mr. Gooch in 1845 in experiments to obtain information for presentation to the Gauge Commission, before which he appeared as a witness on behalf of the broad gauge as stated above. The boiler pressure was 75 lb. per square inch. The engine made several trips between London and Didcot with a maximum load of 81 tons behind the tender at a maximum speed of 59 miles per hour on a falling gradient—Didcot-London—of 1 in 1070. For the trials with a goods train the engine Sampson was used. It had six wheels coupled, 5ft. diameter, and cylinders 15in. diameter by 18in. stroke. On the same falling gradient the engine obtained an average speed of 25.7 miles per hour with 400 tons behind the tender. Mr. Gooch stated that in 1845 the express trains on the Great Western Railway were timed at an average overall speed of 44.4 miles per hour, and a maximum speed of 60 miles per hour between Twyford and Maidenhead, with loads of 70 or 80 tons behind the tender. The above figures suggest a very interesting comparison of loads and speeds of seventy years ago and those of the present day. The Fishguard boat trains frequently amount to 400 tons behind the tender, and after one stop at Cardiff run the 145 miles 12 chains between Cardiff and Paddington in 4 h. 50 min. over gradients in the Severn Tunnel of 1 in 100 for three miles, and at Badminton of 1 in 300 for 11 miles. Usually drawn by one of the four-cylinder "Star" class, the engine regularly exerts a draw-bar horse-power at 60 miles per hour of 900. On the trials of the Ixion the draw-bar horse-power at the same speed was 390.

For the purpose of recording results at those trials, Mr. Gooch designed and built at Swindon a dynamometer car. It has long since disappeared, and has been replaced by that illustrated in Fig. 28, which shows the interior of the present car used by the technical staff at Swindon. This vehicle weighs 27 tons and is carried on two four-wheel bogies. A specially constructed frictionless spring to which the draw-bar is attached is arranged between the solebars, and connected by an arm bracket to a sliding rod carrying a pen. This records the draw-bar pull on a paper roll, which is wound on a drum and moved across the table at a definite rate of 1ft. or 2ft. of paper to one mile of line traversed. This movement is obtained by suitable gearing connected to an additional flangeless wheel, which may be raised, or lowered at will on to the rail. A datum line is furnished by a fixed pen, and the tractive effort may be measured off by a special scale in tons and decimals of a ton. The actual speed in miles per hour is recorded by a pen, which is connected electrically to an electro-magnet in communication with a clock. The pen is deflected every two seconds, and the speed is read off by a suitable scale. The integrator actuates another pen, which moves over the paper and records the total amount of work done on the draw-bar in foot-pounds. Another pen records the time every five minutes during the run, and stations, mile-posts, &c., are recorded by means of a hand push operated by an observer at one of the windows. Similarly, another observer on the foot-plate of the engine records by an electric push communicating with a pen on the moving paper all alterations to positions of the regulator and reversing gear and changes in the boiler pressure. For brake testing the car is fitted with two special brake cylinders, the strokes of which can be varied, several vacuum gauges, and a duplex mercury column. To obtain a graphic indication of the condition of the permanent way a small apparatus is provided, which consists of a cast iron shell containing a heavy ball suspended on a spring and floating in a suitable fluid. The movements of the ball vertically, transversely, and longitudinally are recorded on a paper roll through the intervention of rubber tubes, the "contained" air of which acts on very sensitive india-rubber diaphragms actuating the pens.

In 1845 the line was being worked by the following engines:—

No.	Type.	Diameter of drivers.	Cylinders.	Heating surface.			Fire-grate area.
				Firebox.	Tubes	Total.	
		ft.	in.	sq. ft.	sq. ft.	sq. ft.	sq. ft.
72	2-2-2	7	15 or 15½ by 18	97	602	699	13·5
30	2-2-2	6	14 by 18	88·7	519	607·7	12·5
22	2-4-0	5	15 by 18	71	396	467	11·4
4	0-6-0	5	15 by 18	—	—	—	—

In his evidence before the Commissioners Mr. Gooch stated that he proposed to build more engines of greater power, and in 1846 the first of his "eight-feet singles," Great Western, was built at Swindon. It was originally of the 2-2-2 type, but the weight on the leading wheels was found to be too much, and another pair was added. The engine had a wagon-top fire-box, but this form was abandoned on the succeeding engines in favour of the ordinary round top fire-box. In this form—4-2-2—twenty-four engines were built at Swindon and seven by an outside builder. The engines were fitted with Gooch link motion. The cylinders were 18in. diameter by 24in. stroke, and the boiler pressure was 120 lb. The tenders of these engines were provided with a seat at the back facing the train for the "travelling porter," whose duty it was to warn the driver if anything happened to the train. We illustrate—Figs. 11—the Lightning, one of these engines, the longitudinal and cross sections of which, Figs. 23 and 24, show the design very clearly.

From 1846, till Mr. Joseph Armstrong's appointment as locomotive superintendent in 1864, Mr. Gooch built at Swindon upwards of 120 0-6-0 type broad gauge 5ft. wheels goods engines. The first twelve had cylinders 16in. diameter by 24in. stroke; but the remainder were given one extra inch in diameter, the stroke remaining the same. In addition to these, sixteen of the "eight-foots" were built, and towards the latter part of this period ten Metropolitan side tanks were turned out with four-coupled wheels 6ft. diameter and 16in. diameter by 24in. stroke cylinders. During this time also, when engines of the older types were brought in for repairs, opportunity was taken to improve their efficiency, principally in the way of the provision of increased boiler and cylinder capacity. In all cases the Gooch link motion was substituted for the old gab gear with its obvious limitations.

With the advent of the "mixed gauge" and the amalgamation of other lines came the need for building narrow gauge locomotives. Swindon built the first in 1855, but Wolverhampton became the chief narrow gauge locomotive centre, and it remained so from 1859, when the first engine was built, until Mr. Dean's removal from there to Swindon in 1877, on his appointment as chief locomotive, carriage and wagon superintendent. In 1876 occurred the amalgamation of the Bristol and Exeter and South Devon and Cornwall Railways with the Great Western. This added nearly two hundred broad gauge locomotives to the existing stock. These were principally tank engines. We illustrate—Figs. 8 and 9—one of the old Bristol and Exeter tank engines, with 8ft. 10in. driving wheels and a bogie at each end. The bogie centres were

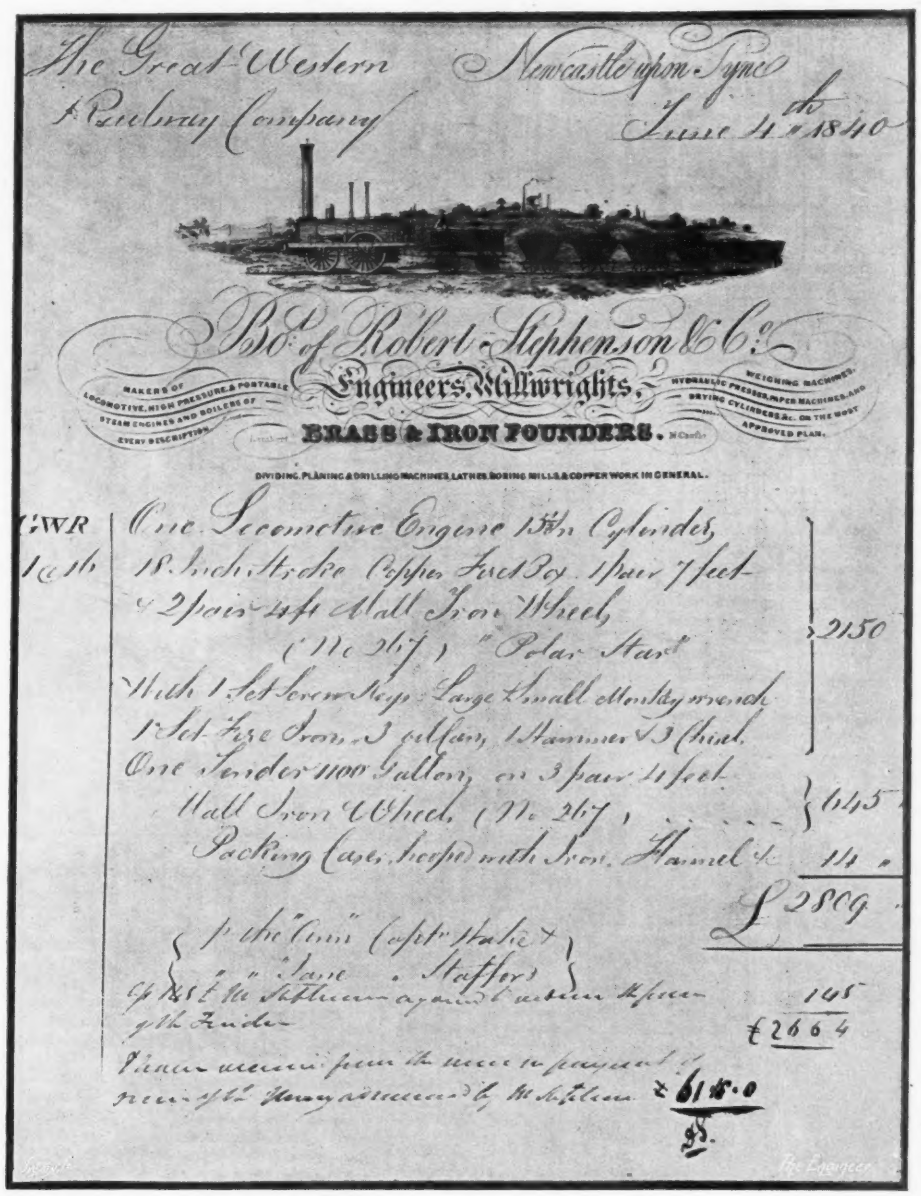

The Great Western Railway Company
Newcastle upon Tyne
June 4th 1840
Bo. of Robert Stephenson & Co.
Engineers, Millwrights,
BRASS & IRON FOUNDERS.
MAKERS OF LOCOMOTIVE, HIGH PRESSURE & PORTABLE STEAM ENGINES AND BOILERS OF EVERY DESCRIPTION
WEIGHING MACHINES, HYDRAULIC PRESSES, PAPER MACHINES, AND DRYING CYLINDERS &c. ON THE MOST APPROVED PLAN.
DIVIDING, PLANING & DRILLING MACHINES, LATHES, BORING MILLS & COPPER WORK IN GENERAL.
One Locomotive Engine 15in Cylinders
18 Inch Stroke Copper Fired Boy 1 pair 7 feet
& 2 pair 4ft 6 all Iron Wheels
(No 367) "Polar Star"
With 1 Set Screw Keys Large & small Monkey wrench
1 Set Fire Irons, 3 Gallon, 1 Hammer & 3 Chisel
One Tender 1100 Gallon, on 3 pair 4 feet
all Iron Wheels (No 367)
Packing Case, heaped with Iron, Flannel &c
£2809
per the "Ann" Capt Hale
& 18 & 19 "Jane" Stafford
145
£2664
£615.0

Fig. 21—INVOICE OF THE POLAR STAR LOCOMOTIVE

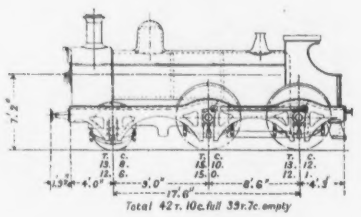


Fig. I.—February, 1889.

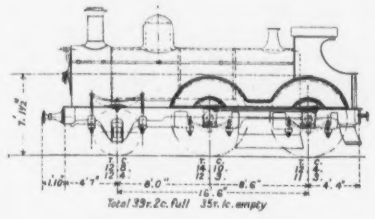


Fig. II.—September 1892.

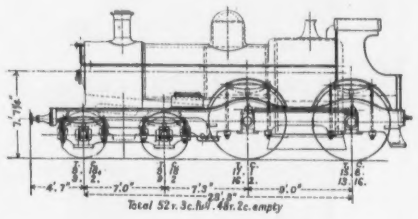


Fig. III.—December, 1897.

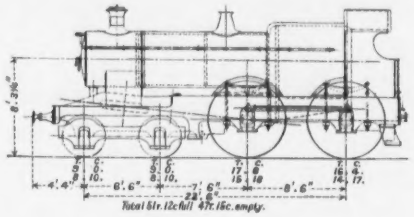


Fig. IV.—April, 1900.

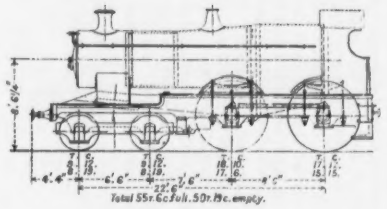


Fig. V.—March, 1903.

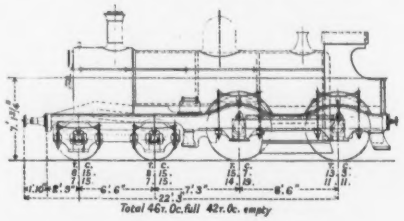


Fig. VI.—May, 1895.

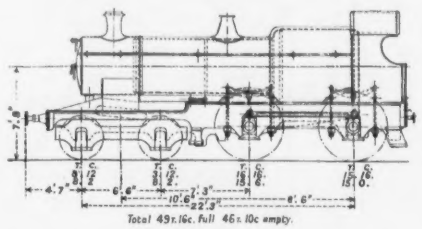


Fig. VII.—May, 1900.

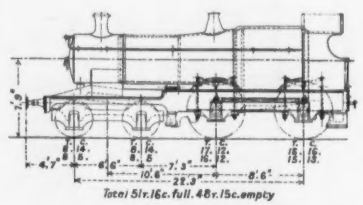


Fig. VIII.—September, 1903.

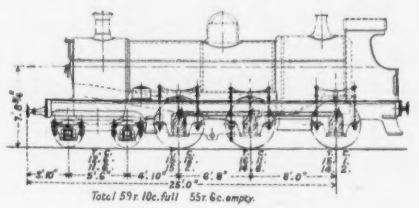


Fig. IX.—August, 1896.

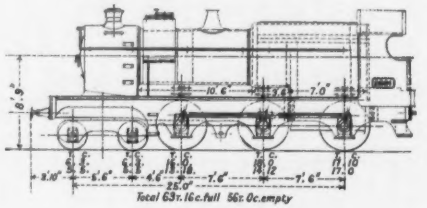


Fig. X.—December, 1899.

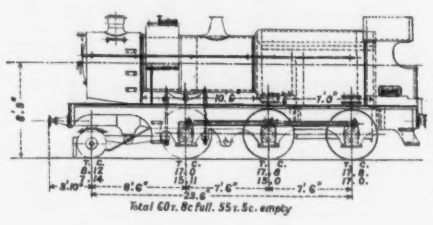


Fig. XI —June, 1901.

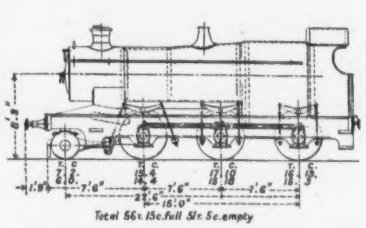


Fig. XII.—August, 1900.

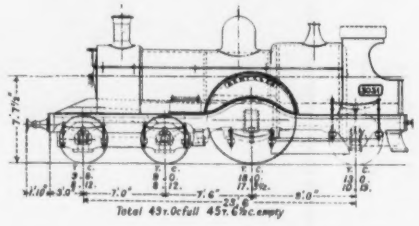


Fig. XIII.—Originally Broad Gauge 2.2.2 in 1891.
Altered to 4.2.2 Narrow Gauge in 1901.

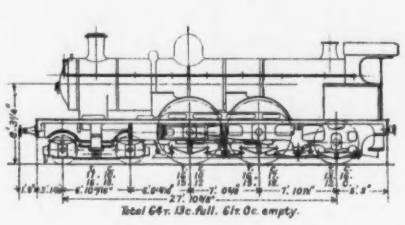


Fig. XIV.—October, 1903.

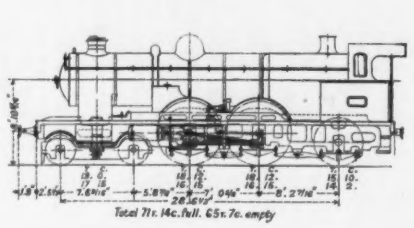


Fig. XV.—June, 1905.

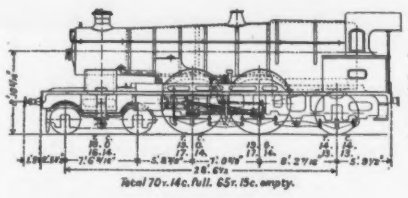


Fig. XVI.

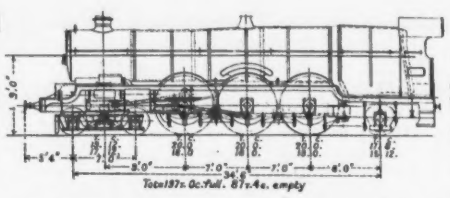


Fig. XVII.—"The Great Bear," February, 1908.

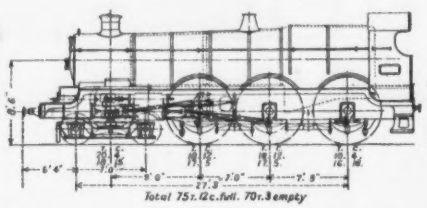


Fig. XVIII.—"Stars," "Kings," "Knights," & "Queens."
Feb., 1907; March, 1908; June, 1909; October, 1910.

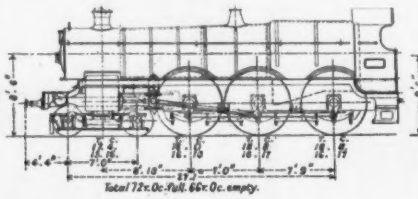


Fig. XIX.—February, 1902.

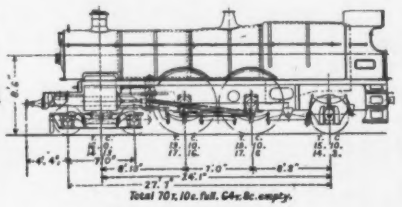


Fig. XX.—February, 1905.

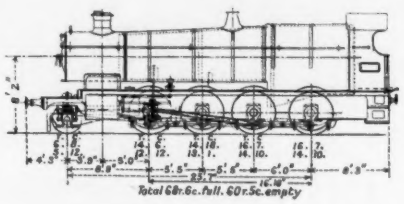


Fig. XXI.—June, 1903.

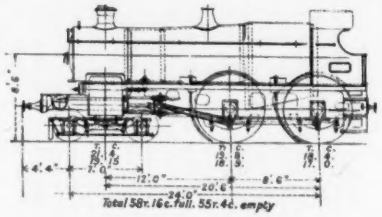


Fig. XXII.—"Counties," May, 1904.

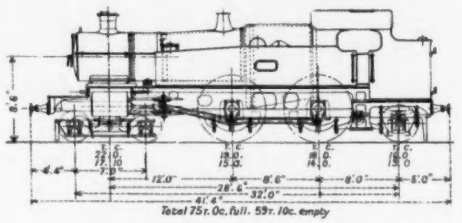


Fig. XXIII.—December, 1905.

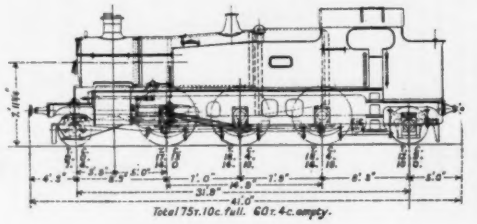


Fig. XXIV.—September, 1903.

5ft. 6in., centre of leading bogie to centre of driving wheel 9ft. 8in., and centre of driving wheel to centre of trailing bogie 10ft. 4in. The weight on each bogie was 15 tons 12 cwt., and on the driving wheels, which were flangeless, 18 tons, making a total weight of 49 tons 4 cwt. One thousand gallons of water were carried in the back tank, and 400 gallons in the tank between the frames. The engines were built by Rothwell and Co. in 1868, and were designed by Mr. Pearson, of the Bristol and Exeter Railway, for express traffic between Bristol and Exeter. The boiler had a total heating surface of 1235 square feet, and fire-grate area of 24 square feet. The cylinders were 18in. diameter and 24in. stroke. The reproductions are very interesting, showing clearly the construction of the engines. They had single frames, except at the driving wheel, where an outside frame provided another bearing. The spring gear of these two bearings was equalised by a rocking shaft above the driving wheel. The bogies took the weight at the centre pin, but the leading bogie was fitted with a peculiar system of side control which came into operation when rounding a curve. The engines were fitted with a hand brake which operated only on the trailing bogie. The engines were altered in 1876 by Mr. Dean to broad gauge tender engines, the trailing bogie was taken away, and a pair of 4ft. 6in. trailing wheels substituted. They ran in this condition, 4-4-2 type, until 1890, when they were broken up.

In 1889 Mr. Dean produced 20 narrow gauge 2-4-0 class engines, shown by Diagram i., p. xii., with 6ft. 2in. driving wheels, and in 1892 he built twenty to the same design, but with 6ft. 8½in. driving wheels, shown by Diagram ii. In 1891 appeared the first single wheel engine with 7ft. 8½in. driving wheels. Eight of these were built in this year, 2-2-2 type, broad gauge, but designed to be easily convertible to narrow gauge. This was done in 1892, and two others built. Afterwards a bogie was substituted for the single pair of leading wheels—Diagram xiii. In 1894 thirty of these were built, and twenty in 1897. These engines have done some excellent work with light loads, but are not suitable for present-day heavy traffic, being short of adhesion, and they are being gradually broken up, as the need for heavier engines occurs. On Saturday and Sunday, the 21st and 22nd of May, 1892, the broad gauge was finally abolished, and the narrow gauge of 4ft. 8½in. between rails became standard for the whole of the system, in common with the other great railways. Preparations for the conversion had been quietly made for many years previously by building engines, carriages, and wagons that were "convertible." All the engines and most of the carriages and wagons were sent to Swindon for conversion or breaking up, and our illustration — Fig. 29 — shows a portion of the broad gauge engines on the sidings at Swindon, twenty miles of which were specially laid down for the reception of the broad gauge stock. At the date of conversion the broad gauge stock was as follows:—

Engines.		Carriages.		Wagons.	
Convertible.	Unconvertible.	Convertible.	Unconvertible.	Convertible.	Unconvertible.
130	67	426	129	792	2477
Total	197	Total	555	Total	4021

By the substitution of new axles the convertible engines were soon running again, and by means of specially designed drop pits in the shops at Swindon narrow gauge bogies were speedily substituted for broad gauge under the carriages. The conversion was the subject of many articles in the engineering journals at the time, even Mr. *Punch* making it the subject of a special cartoon. We published a full account in our issues of May 13th, 20th, and 27th, 1892.

In 1895 Mr. Dean built the first engine of 4-4-0 type, 5ft. 8in. driving wheels - Diagram vi.—for service in South Devon, and so successful was this engine that forty of the type were built in 1895 and 1896.

In the latter year the first 4-6-0 type engine, with 4ft. 7½in. driving wheels, and 20in. stroke by 24in. diameter cylinders, was built for heavy goods work—Diagram ix.—and in 1899 a modification of this design produced the "Krugers"; these had 4ft. 7½in. driving wheels, and cylinders 19in. diameter by 28in. stroke, fitted with piston valves. The boiler had a Belpaire fire-box and a combustion chamber—Diagram x. The first engine, 2601, was originally fitted with a bogie at the leading end, but this was afterwards replaced by a pony truck, and the succeeding nine engines were thus built, except that the sand box was taken off the barrel of the later engines—Diagram xi.

In 1897 the "Badmintons," forerunners of the "Cities," were built—Diagram iii. These engines have the same cylinders and motion as the "Devonshires," already referred to—Diagram vi. The first Belpaire boiler built at Swindon was put on the first engine of this lot, and from this time this type of fire-box has been adopted for all new boilers built at Swindon, except so far as it has been necessary to re-boiler the older engines with round-top fire-boxes to prevent extensive alterations to tanks, &c

In 1898, 1899, and 1900 sixty more of the "Devonshires"—Diagram vii.—were built, the last twenty of which, "Bulldogs," were fitted with the standard No. 2 boiler, having a Belpaire fire-box and drum head tube plates; and instead of the outside frame being cut down between the driving and trailing wheels, they were continued straight through. In this form, and with the exception that the boiler barrel is coned, 105 engines have since been built—Diagram viii. In 1900 and 1901 forty engines, "Atbaras," a further development of the "Badmintons," were built. These had the same cylinders and motion, straight frames similar to the "Bulldogs," and the standard No. 2 boiler. Twenty similar engines, "Flowers," were built in 1908. In 1903 ten engines, "Cities," similar to the above, were built with a larger boiler, standard No. 4 - Diagram v.

In August, 1900, the first of the "Aberdares" 2-6-0 class was built. This class is a successor of the "Krugers," but has cylinders and motion the same as the "Bulldogs" and "Cities," and a standard No. 2 boiler. In 1901 forty more of these were built to the same drawings. Since that time fifty others have been built, but have been fitted with larger boilers, standard No. 4—Diagram xii.

Towards the latter part of Mr. Dean's time it was becoming more obvious, in view of the ever increasing demands of the traffic department for the provision of greater locomotive power, and to avoid the necessity for "double-heading" that locomotive design should be thoroughly reviewed. Mr. Churchward, who succeeded Mr. Dean in 1902, decided on six leading types, general dimensions of which are given in the table below.

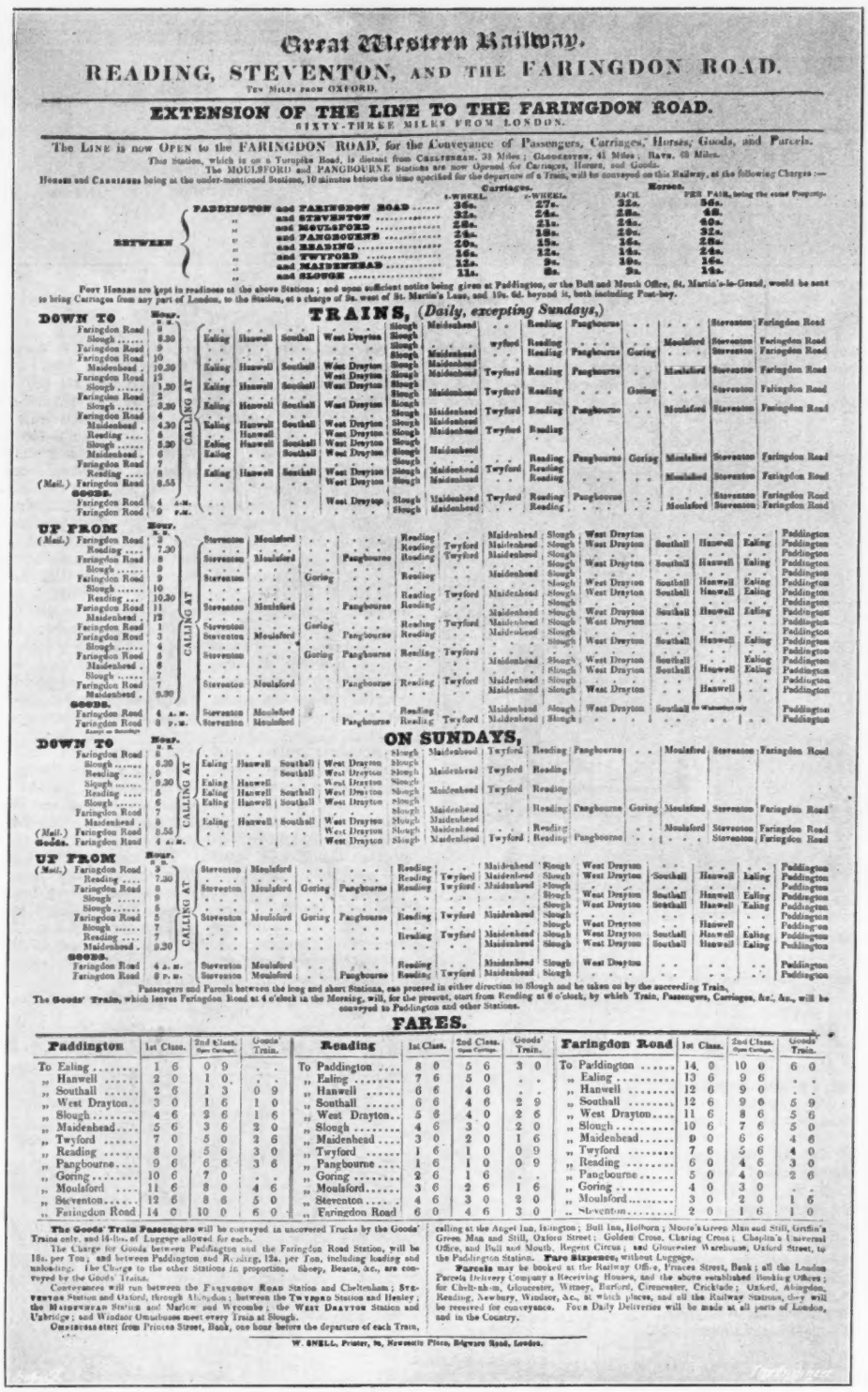
The first engine of the series was No. 100. 4-6-0 type, built early in 1902—Diagram xix. The boiler had a straight barrel, but on the next and succeeding engines the barrel is coned. In June, 1903, the first of the 2-8-0 type was built — engine No. 97—Diagram xxi.—and in September, 1903, the first of the 2-6-2 tank engines, No. 99, was put into traffic—Diagram xxiv. This was followed in May, 1904, by the first of the "Counties," No. 3473, 4-4-0 type — Diagram xxii. - and in December, 1905, the first of the "County" tanks was introduced, 4-4-2 type—Diagram xxiii.

In working out these designs the need for standardisation of the different details, a consequent reduction in first cost, and a reduced stock necessary for upkeep has been fully borne in mind. A short examination will illustrate this point.

All cylinders are outside the frames, and are 18in. diameter by 30in. stroke. They are fitted with piston valves 10in. diameter, which are actuated by Stephenson's link motion through a rocking shaft from excentrics on the driving axle between the frames.

As a consequence, the cylinders, motion, and expansion gear are standard for the whole series, with the exception that two lengths of excentric rods and connecting-rods are required. The coupled wheels have axles and axle-boxes alike in all respects. The bogie is of a standard design, and is inter-

Wheel Arrangement.	Diameter of coupled wheels.	Boiler.	Total heating surface.	Boiler pressure.
	ft. in.		sq. ft.	lb.
4-6-0	6 8½	No. 1	2143	225
4-4-2	6 8½	No. 1	2143	225
2-8-0	4 7½	No. 1	2143	225
4-4-0	6 8½	No. 4	1820	200
4-4-2 tank ...	6 8½	No. 2	1518	200
2-6-2 tank ...	5 8	No. 2	1518	200



Great Western Railway.

READING, STEVENTON, AND THE FARINGDON ROAD.

TEN MILES FROM OXFORD.

EXTENSION OF THE LINE TO THE FARINGDON ROAD.

SIXTY-THREE MILES FROM LONDON.

The LINE is now OPEN to the FARINGDON ROAD, for the Conveyance of Passengers, Carriages, Horses, Goods, and Parcels.

The Station, which is on a Turnpike Road, is distant from CHELTENHAM, 39 Miles; GLOUCESTER, 41 Miles; BATH, 69 Miles.

The MOULSFORD and PANGBOURNE Stations are now Opened for Carriages, Horses, and Goods.

HORSES and CARRIAGES being at the under-mentioned Stations, 10 minutes before the time specified for the departure of a Train, will be conveyed on this Railway, at the following Charges:—

		Carriages. 4-WHEEL.	Carriages. 2-WHEEL.	Horses. EACH.	Horses. PER PAIR, being the same Property.
BETWEEN	PADDINGTON and FARINGDON ROAD	26s.	27s.	32s.	56s.
	" and STEVENTON	32s.	24s.	28s.	46.
	" and MOULSFORD	28s.	21s.	24s.	40s.
	" and PANGBOURNE	24s.	18s.	20s.	32s.
	" and READING	20s.	15s.	16s.	28s.
	" and TWYFORD	16s.	12s.	14s.	24s.
	" and MAIDENHEAD	12s.	9s.	10s.	16s.
	" and SLOUGH	11s.	8s.	9s.	14s.

Post Horses are kept in readiness at the above Stations; and upon sufficient notice being given at Paddington, or the Bull and Mouth Office, St. Martin's-le-Grand, would be sent to bring Carriages from any part of London, to the Station, at a charge of 5s. west of St. Martin's Lane, and 10s. 6d. beyond it, both including Post-boy.

TRAINS, (*Daily, excepting Sundays,*)

DOWN TO	Hour. A.M.	CALLING AT													
Faringdon Road	9						Slough	Maidenhead	. .	Reading	Pangbourne	. .	. . .	Steventon	Faringdon Road
Slough	8.30	Ealing	Hanwell	Southall	West Drayton	Slough			wyford	Reading	. .	. .	Moulsford	Steventon	Faringdon Road
Faringdon Road	9	. .	. .	. .	. .	Slough	Maidenhead			Reading	Pangbourne	Goring	. . .	Steventon	Faringdon Road
Faringdon Road	10	. .	. .	. .	. .	Slough	Maidenhead	Twyford	Reading	Pangbourne	. .	Moulsford	Steventon	Faringdon Road	
Maidenhead .	10.30	Ealing	Hanwell	Southall	West Drayton	Slough	Maidenhead								
Faringdon Road	13	. .	. .	. .	. .	Slough									
Slough	1.20	Ealing	Hanwell	Southall	West Drayton	Slough	Maidenhead	Twyford	Reading	. . .	Goring	. . .	Steventon	Faringdon Road	
Faringdon Road	2	. .	. .	. .	. .	Slough									
Slough	3.30	Ealing	Hanwell	Southall	West Drayton	Slough	Maidenhead	Twyford	Reading	Pangbourne	. .	Moulsford	Steventon	Faringdon Road	
Faringdon Road	4					Slough									
Maidenhead .	4.30	Ealing	Hanwell	Southall	West Drayton	Slough	Maidenhead	Twyford	Reading						
Reading	5		Hanwell		West Drayton	Slough									
Slough	5.30	Ealing	Hanwell	Southall	West Drayton	Slough									
Maidenhead .	6	Ealing	. .	Southall	West Drayton	Slough	Maidenhead								
Faringdon Road	7	. .	. .	. .	. .	Slough				Reading	Pangbourne	Goring	Moulsford	Steventon	Faringdon Road
Reading	8	Ealing	Hanwell	Southall	West Drayton	Slough	Maidenhead	Twyford	Reading						
(*Mail.*) Faringdon Road	8.55				West Drayton	Slough	Maidenhead	. .	Reading	. . .	. .	Moulsford	Steventon	Faringdon Road	
GOODS.															
Faringdon Road	4 A.M.	. .	. .	. .	West Drayton	Slough	Maidenhead	Twyford	Reading	Pangbourne	. .	. .	Moulsford	Steventon	Faringdon Road
Faringdon Road	9 P.M.	. .	. .	. .		Slough	Maidenhead		Reading						

UP FROM	Hour. A.M.	CALLING AT													
(*Mail.*) Faringdon Road	9		Steventon	Moulsford	. .	. . .	Reading	. .	Maidenhead	Slough	West Drayton				Paddington
Reading	7.30						Reading	Twyford	Maidenhead	Slough	West Drayton	Southall	Hanwell	Ealing	Paddington
Faringdon Road	8		Steventon	Moulsford	. .	Pangbourne	Reading	Twyford	Maidenhead	Slough	. . .				Paddington
Slough	9		. . .	. . .	. .	. . .	. .	. .	. .	Slough	West Drayton	Southall	Hanwell	Ealing	Paddington
Faringdon Road	9		Steventon	. . .	Goring	. . .	Reading	. .	Maidenhead	Slough	. . .				Paddington
Slough	10		. . .	. . .	. .	. . .	. .	. .	. .	Slough	West Drayton	Southall	Hanwell	Ealing	Paddington
Reading	10.20		. . .	. . .	. .	. . .	Reading	Twyford	Maidenhead	Slough	West Drayton	Southall	Hanwell	Ealing	Paddington
Faringdon Road	11		Steventon	Moulsford	. .	Pangbourne	Reading	. .	. .	Slough	. . .				Paddington
Maidenhead .	12		. . .	. . .	. .	. . .	. .	. .	Maidenhead	Slough	West Drayton	Southall	Hanwell	Ealing	Paddington
Faringdon Road	1		Steventon	. . .	Goring	. . .	Reading	Twyford	Maidenhead	Slough	West Drayton	. .	. .	. .	Paddington
Faringdon Road	3		Steventon	Moulsford	. .	Pangbourne	Reading	. .	Maidenhead	Slough	. . .				Paddington
Slough	4		. . .	. . .	. .	. . .	. .	. .	. .	Slough	West Drayton	Southall	Hanwell	Ealing	Paddington
Faringdon Road	5		Steventon	. . .	Goring	Pangbourne	Reading	Twyford	. .	. .	. . .				Paddington
Maidenhead .	6		. . .	. . .	. .	. . .	. .	. .	Maidenhead	Slough	West Drayton	Southall	. .	Ealing	Paddington
Slough	7		. . .	. . .	. .	. . .	. .	. .	. .	Slough	West Drayton	Southall	Hanwell	Ealing	Paddington
Faringdon Road	7		Steventon	Moulsford	. .	Pangbourne	Reading	Twyford	Maidenhead	Slough	. . .				Paddington
Maidenhead .	9.30		. . .	. . .	. .	. . .	. .	. .	Maidenhead	Slough	West Drayton	. .	Hanwell	. .	Paddington
GOODS.															
Faringdon Road	4 A.M.		Steventon	Moulsford	. .	. . .	Reading	. .	Maidenhead	Slough	West Drayton	Southall	. .	. .	Paddington
Faringdon Road	8 P.M.		Steventon	Moulsford	. .	Pangbourne	Reading	Twyford	Maidenhead	Slough	. . .				Paddington

ON SUNDAYS,

DOWN TO	Hour. A.M.	CALLING AT													
Faringdon Road	8						Slough	Maidenhead	Twyford	Reading	Pangbourne	. .	Moulsford	Steventon	Faringdon Road
Slough	8.30	Ealing	Hanwell	Southall	West Drayton	Slough									
Faringdon Road	9	. .	. .	. .	. .	Slough	Maidenhead		Twyford	Reading					
Slough	9.30	Ealing	Hanwell		West Drayton	Slough									
Reading	8	Ealing	Hanwell	Southall	West Drayton	Slough	Maidenhead	Twyford	Reading						
Slough	6	Ealing	Hanwell	Southall	West Drayton	Slough									
Faringdon Road	7	. .	. .	. .	. .	Slough	Maidenhead		. .	Reading	Pangbourne	Goring	Moulsford	Steventon	Faringdon Road
Maidenhead .	8	Ealing	Hanwell	Southall	West Drayton	Slough	Maidenhead								
(*Mail.*) Faringdon Road	8.56	. .	. .	. .	West Drayton	Slough	Maidenhead			Reading			Moulsford	Steventon	Faringdon Road
Goods. Faringdon Road	4 A.M.	. .	. .	. .	West Drayton	Slough	Maidenhead	Twyford	Reading	Pangbourne	. .	. .	. .	Steventon	Faringdon Road

UP FROM	Hour. P.M.	CALLING AT													
(*Mail.*) Faringdon Road	9		Steventon	Moulsford	. .	. . .	Reading	. .	Maidenhead	Slough	West Drayton				Paddington
Reading	7.30						Reading	Twyford	Maidenhead	Slough	West Drayton	Southall	Hanwell	Ealing	Paddington
Faringdon Road	8		Steventon	Moulsford	Goring	Pangbourne	Reading	Twyford	Maidenhead	Slough	. . .				Paddington
Slough	9		. . .	. . .	. .	. . .	. .	. .	. .	Slough	West Drayton	Southall	Hanwell	Ealing	Paddington
Slough	5		. . .	. . .	. .	. . .	. .	. .	. .	Slough	West Drayton	Southall	Hanwell	Ealing	Paddington
Faringdon Road	5		Steventon	Moulsford	Goring	Pangbourne	Reading	Twyford	Maidenhead	Slough	. . .				Paddington
Slough	7		. . .	. . .	. .	. . .	. .	. .	. .	Slough	West Drayton	. .	Hanwell		Paddington
Reading	7		. . .	. . .	. .	. . .	Reading	Twyford	Maidenhead	Slough	West Drayton	Southall	Hanwell	Ealing	Paddington
Maidenhead .	9.30		. . .	. . .	. .	. . .	. .	. .	Maidenhead	Slough	West Drayton	Southall	Hanwell	Ealing	Paddington
GOODS.															
Faringdon Road	4 A.M.		Steventon	Moulsford	. .	. . .	Reading	. .	Maidenhead	Slough	West Drayton	. .	. .	. .	Paddington
Faringdon Road	8 P.M.		Steventon	Moulsford	. .	Pangbourne	Reading	Twyford	Maidenhead	Slough	. . .				Paddington

Passengers and Parcels between the long and short Stations, can proceed in either direction to Slough and be taken on by the succeeding Train.

The Goods' Train, which leaves Faringdon Road at 4 o'clock in the Morning, will, for the present, start from Reading at 6 o'clock, by which Train, Passengers, Carriages, &c., &c., will be conveyed to Paddington and other Stations.

FARES.

Paddington	1st Class.	2nd Class. Open Carriage.	Goods' Train.
To Ealing	1 6	0 9	. .
,, Hanwell	2 0	1 0	. .
,, Southall	2 6	1 3	0 9
,, West Drayton..	3 0	1 6	1 0
,, Slough	4 6	2 6	1 6
,, Maidenhead	5 6	3 6	2 0
,, Twyford	7 0	5 0	2 6
,, Reading	8 0	5 6	3 0
,, Pangbourne	9 6	6 6	3 6
,, Goring	10 6	7 0	. .
,, Moulsford	11 6	8 0	4 6
,, Steventon	12 6	8 6	5 0
,, Faringdon Road	14 0	10 0	6 0

Reading	1st Class.	2nd Class. Open Carriage.	Goods' Train.
To Paddington	8 0	5 6	3 0
,, Ealing	7 6	5 0	. .
,, Hanwell	6 6	4 6	. .
,, Southall	6 6	4 6	2 9
,, West Drayton..	5 6	4 0	2 6
,, Slough	4 6	3 0	2 0
,, Maidenhead	3 0	2 0	1 6
,, Twyford	1 6	1 0	0 9
,, Pangbourne	1 6	1 0	0 9
,, Goring	2 6	1 6	. .
,, Moulsford.....	3 6	2 6	1 6
,, Steventon	4 6	3 0	2 0
,, Faringdon Road	6 0	4 6	3 0

Faringdon Road	1st Class.	2nd Class. Open Carriage.	Goods' Train.
To Paddington	14 0	10 0	6 0
,, Ealing	13 6	9 6	. .
,, Hanwell	12 6	9 0	. .
,, Southall	12 6	9 6	5 9
,, West Drayton....	11 6	8 6	5 6
,, Slough	10 6	7 6	5 0
,, Maidenhead.....	9 0	6 6	4 6
,, Twyford	7 6	5 6	4 0
,, Reading	6 0	4 6	3 0
,, Pangbourne.....	5 0	4 0	2 6
,, Goring	4 0	3 0	. .
,, Moulsford.....	3 0	2 0	1 6
,, Steventon.....	2 0	1 6	1 0

The Goods' Train Passengers will be conveyed in uncovered Trucks by the Goods' Trains only, and 14-lbs. of Luggage allowed for each.

The Charge for Goods between Paddington and the Faringdon Road Station, will be 10s. per Ton; and between Paddington and Reading, 12s. per Ton, including loading and unloading. The Charge to the other Stations in proportion. Sheep, Beasts, &c., are conveyed by the Goods' Trains.

Conveyances will run between the FARINGDON ROAD Station and Cheltenham; STEVENTON Station and Oxford, through Abingdon; between the TWYFORD Station and Henley; the MAIDENHEAD Station and Marlow and Wycombe; the WEST DRAYTON Station and Uxbridge; and Windsor Omnibuses meet every Train at Slough.

OMNIBUSES start from Princes Street, Bank, one hour before the departure of each Train, calling at the Angel Inn, Islington; Bull Inn, Holborn; Moore's Green Man and Still, Gerrin's Green Man and Still, Oxford Street; Golden Cross, Charing Cross; Chaplin's Universal Office, and Bull and Mouth, Regent Circus; and Gloucester Warehouse, Oxford Street, to the Paddington Station. FARE SIXPENCE, without Luggage.

PARCELS may be booked at the Railway Offices, Princes Street, Bank; all the London Parcels Delivery Company's Receiving Houses, and the above established Booking Offices; for Cheltenham, Gloucester, Witney, Burford, Cirencester, Cricklade; Oxford, Abingdon, Reading, Newbury, Windsor, &c., at which places, and all the Railway Stations, they will be received for conveyance. Four Daily Deliveries will be made at all parts of London, and in the Country.

W. SNELL, Printer, 36, Newcastle Place, Edgware Road, London.

Fig. 22—TIME TABLE OF JULY, 1840

changeable in the 4-6-0, 4-4-2, 4-4-0, and 4-4-2 tank engines. The pony truck of the 2-8-0 and 2-6-2 tank engines is also interchangeable.

Three sizes of boilers are necessary. The old broad gauge practice of using a domeless boiler has been adopted with a cone barrel and Belpaire fire-box. Steam is taken from the top of the fire-box to a regulator in the smoke-box. The old form of smoke-box tube plate is discarded, and the "drum head" pattern and round smoke-box is used. This form of smoke-box favours the interchangeability of boilers between this series and the older types of inside cylinder engines which is followed out to a very large extent at Swindon.

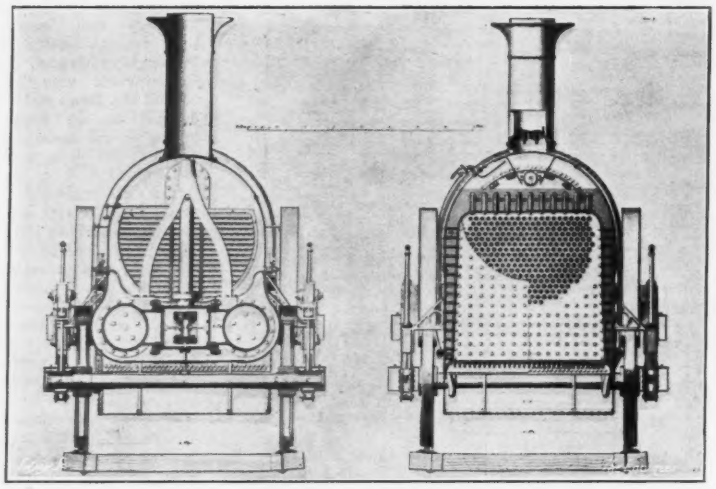


Fig. 24—SECTION OF 8ft. LOCOMOTIVE

An engine "in" for repairs is often turned out in a shorter time by the simple expedient of substituting a new or repaired boiler for its own. As a consequence a greater number of engines are kept in actual service than would otherwise be the case.

It is unfortunately a fact that for the provision of greater power in a locomotive an increased weight is necessary, so that until the permanent way of what one may term the subsidiary portions of a great railway system is brought up to date it is necessary still to provide the older design of lighter and less powerful locomotive. The No. 4 standard boiler of the outside cylinder types interchanges with the "Aberdare" class 2-6-0, and "City" class 4-4-0. No. 2 standard boiler interchanges with the "Bulldog" class. All these engines have 18in. diameter by 26in. stroke inside cylinders, and Stephenson's link motion.

In 1903 the Great Western Railway Company purchased a 4-4-2 de Glehn compound locomotive from the Société Alsacienne de Constructions Mécaniques. Belfort, France—Diagram xiv., page xii. It will be remembered that at this time the de Glehn compounds were doing splendid work on the Chemin de Fer du Nord of France. The engine was named La France, and was put to work in the same "links" as the Swindon-built 4-4-0 and 4-6-0 classes. Later, in 1905, the company purchased from the same makers two more de Glehn compounds, 4-4-2 type—Diagram xv. These were of greater power than La France, and were similar to those just introduced on the Paris-Orleans Railway. They are named President and Alliance. In all three engines the low-pressure cylinders are between the frames and drive the leading axle, which is cranked. The high-pressure cylinders are outside the frames, and drive the second pair of coupled wheels. There are four sets of expansion gear of the Walschaerts type, and the cut-offs for high and low-pressure cylinders can be varied at the will of the driver. Following out the practice of interchanging boilers, No. 104 was in 1907 fitted with No. 1 standard boiler similar to the 4-6-0 class.

For dealing with long non-stop traffic, as, for instance, the Cornish "Riviera" trains, and the Fishguard boat trains, Swindon, early in 1907, produced the well-known "Stars," the general view of which we give in Fig. 25. The first engine—No. 40—was built experimentally with a 4-4-2 wheel arrangement, in 1906, and later altered to 4-6-0 type. Two of these engines, Polar Star and Lode Star, were used recently in the trials on the North-Western and Great Western Railways. They have a greater tractive effort than the 4-6-0 two-cylinder engines. The cylinders are four in number, 14½in. in diameter, and 26in. stroke, all using steam of 225 lb. pressure, and are fitted with 8in. diameter piston valves. The inside cylinders drive the leading coupled axle, and the outside cylinders drive the intermediate coupled wheels, the crank being set on the four quarters. Two sets of Walschaerts valve gear, driven from excentrics on the crank axle between the frames, actuate the valves of all four cylinders, a rocking shaft connecting the outside valve rod with that of its corresponding inside cylinder. The boiler is interchangeable with that of the 4-6-0 two cylinder engines. So successful were these engines, that two "lots" of ten each, "Knights" and "Kings" have since been constructed, and at the present time ten others, to be named "Queens," are under construction at Swindon—Fig. 26.

Early in 1908 the first engine of the "Pacific" type in this country, No. 111, the Great Bear, was built. This engine is a further development of the "Stars," and has four cylinders, 15in. diameter and 26in. stroke. The motion, expansion gear, wheels and axles, and bogie, are similar to the "Stars," and the provision of an additional pair of carrying wheels under the fire-box enables a very large boiler—No. 6—to be provided.

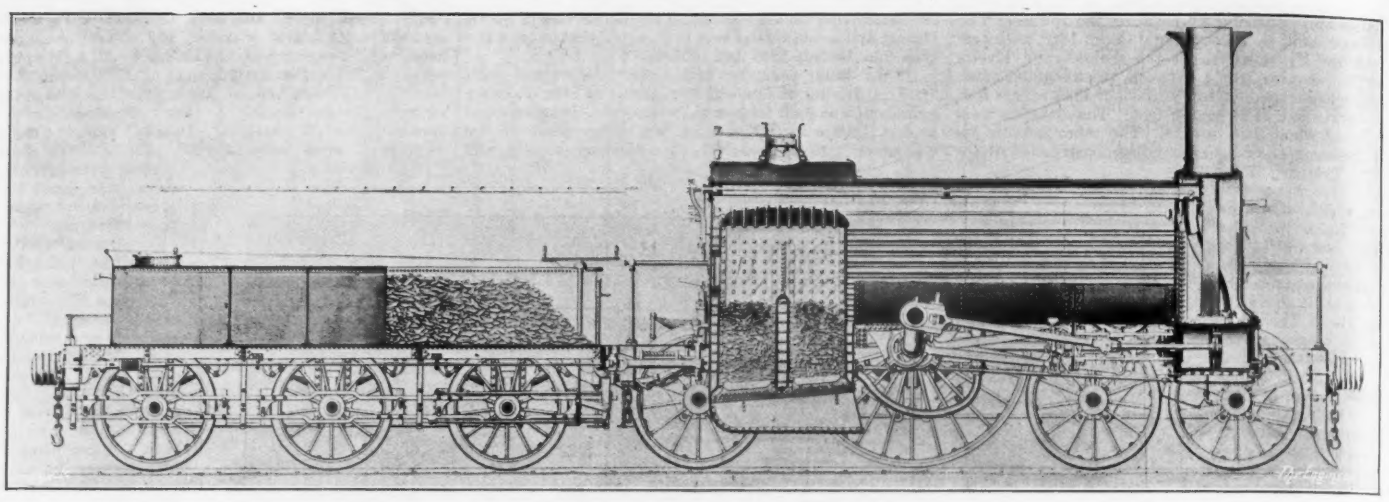


Fig. 23—BROAD GAUGE ENGINE WITH 8ft. DRIVERS

As will be seen from diagram No. xvii., the fixed wheel base, *i.e.*, from bogie centre to centre of trailing wheels, is 34ft. 6in., and the driving or rigid wheel base has been reduced from 14ft. 9in., which is that of the "Stars," to 14ft. The trailing carrying wheels run in a radial axle-box, which has ample side play to allow the engine to negotiate curves. The boiler is fitted with a superheater of the Swindon type. The boiler barrel is 23ft. long, and tapers from 5ft. 6in. diameter at the smoke-box to 6ft. diameter at the fire-box, which is of the Belpaire type. It is sloped backwards to clear the trailing coupled wheels, and is 8ft. long and 6ft. wide at the foundation ring, tapering upwards at the sides to 5ft. 9in. The fire-brick arch was originally carried by four steel tubes 3in. internal diameter, but after working some time these tubes burnt through, and the arch is now carried in the usual way on the sides of the fire-box. The smoke-box is bolted to the cylinders and the saddle casting, and the boiler is carried at the fire-box by a special sliding bracket at the front end, and a flexible plate bracket at the back to allow for expansion. The bogie is of the same design as that of the "Stars," and is interchangeable with that class.

The tender, which is of an experimental design, differs from the standard Great Western Railway tender, in that it is carried on two bogies, which are identical with the engine bogie except in wheel base. The tank is 3500 gallons capacity, and the coal capacity is six tons. The overall wheel base of the engine and tender is 61ft. 0½in., which makes it possible to turn on a standard 65ft. turntable.

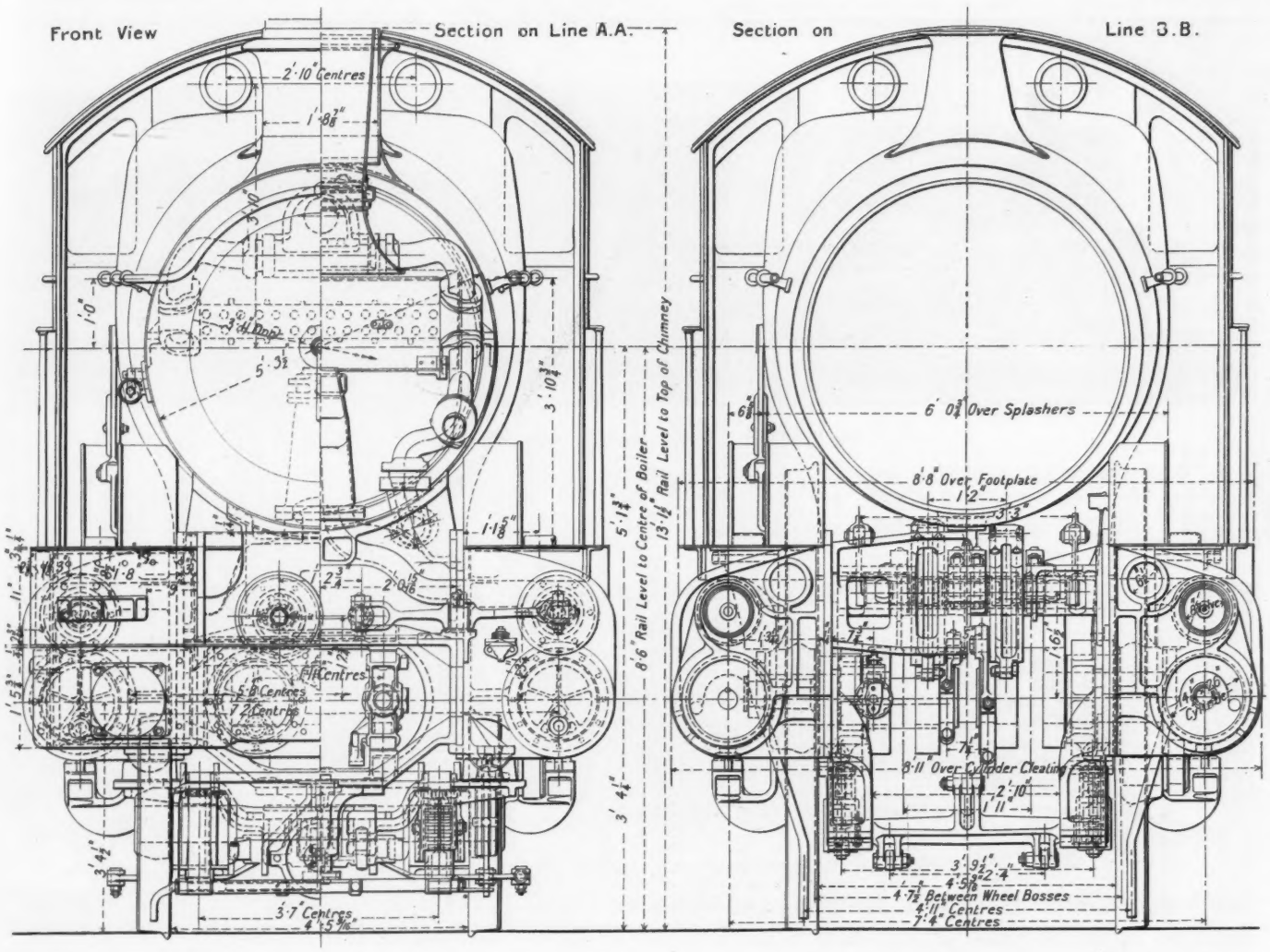
The engine has been employed almost exclusively

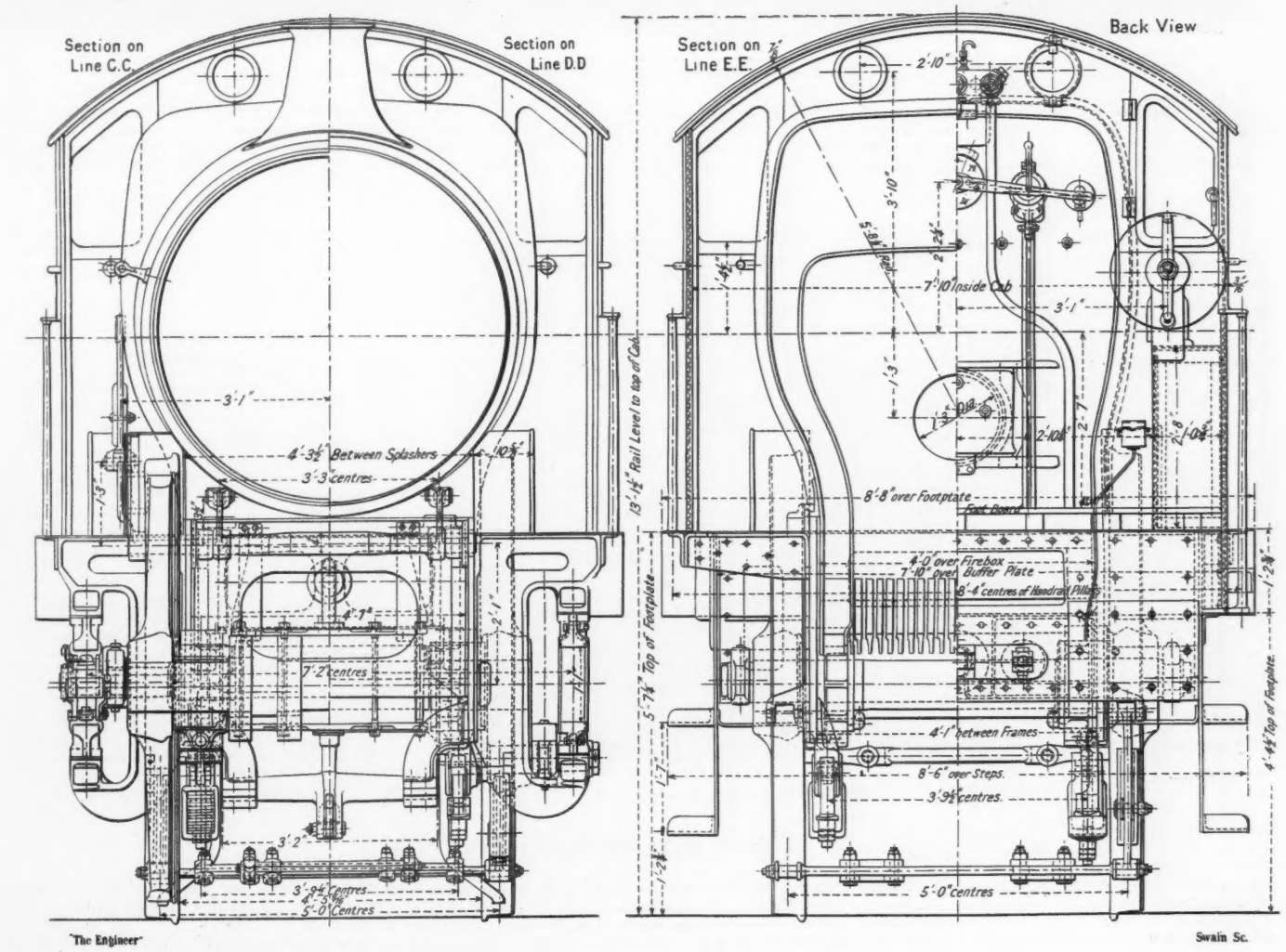
STANDARD GAUGE ENGINES OF THE GREAT WESTERN RAILWAY—(*See page* xii.)

Diagram.	Type.	Cylinders.	Diameter of coupled wheels.	Heating surface.				Grate area.	Boiler pressure, per sq. in.	Tractive effort.	Adhesion weight.	Tank or tender capacity.
				Fire-box.	Tubes.	Superheating surface.	Total.					
		in. in.	ft. in.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	lb.	lb.	tons.	gals.
I. ...	2-4-0	2 18 × 24	6 2	116	1353	—	1469	19	150	14,190	9·1	3000
II. ...	2-4-0	2 17½ × 24	6 8½	99	1265	—	1364	17	150	12,326	26·7	3000
III. ...	4-4-0	2 18 × 26	6 8½	121	1350§	—	1471§	18·3	180	16,952	32·35	3000
IV. .	4-4-0	2 18 × 26	6 8½	125	1538	—	1663	21·5	180	16,952	33·6	3000
V. ...	4-4-0	2 18 × 26	6 8½	128	1690	—	1818	20·5	200	18,836	33·1	3000
V. ..	4-4-0	2 18 × 26	6 8½	129	1223	215	1567	20·5	200	18,836	36·1	3000
VI. ...	4-4-0	2 18 × 26	5 8	115	1286	—	1401	19	165	18,396	28·5	2000
VII. ...	4-4-0	2 18 × 26	5 8	125	1538	—	1663	21·5	180	20,069	32·6	2500
VIII. ...	4-4-0	2 18 × 26	5 8	121	1397	—	1518	20·5	195	21,741	34·4	2500
VIII. ..	4-4-0	2 18 × 26	5 8	122	907	185	1214	20·5	195	21,741	34·4	2500
IX. ...	4-6-0	2 20 × 24	4 7½	116	1402	—	1518	35	165	25,687	47·2	2500
X. ...	4-6-0	2 19 × 28	4 7½	167	1713	—	1880	32	180	29,504	51·5	3000
XI. ..	2-6-0	2 19 × 28	4 7½	167	1713	—	1880	32	180	29,504	51·8	3000
XII. ...	2-6-0	2 18 × 26	4 7½	128	1690	—	1818	20·5	200	27,322	49·65	3000
XII. ...	2-6-0	2 18 × 26	4 7½	129	1223	215	1567	20·5	200	27,322	49·65	3000
XIII. ...	4-2-2	2 19 × 24	7 8½	124	1343	—	1467	20·8	160	13,415	18·0	3000
XIV. ...	4-4-2	4 13⅜ / 22½ × 25⅝	6 8½	167	2289§	—	2456	29·5	227	24,382	33·35	3500
XV. ...	4-4-2	4 14⅜ / 23⅜ × 25⅝	6 8½	173	2583§	—	2756	33·3	227	27,713	37·20	3500
XVI. ...	4-4-2	,, ,,	6 8½	154	1989	—	2143	27	225	27,644	38·0	3500
XVII. ...	4-6-2	4 15 × 26	6 8½	158	2698	545	3401	42	225	29,430	60·0	3500
*XVIII. ...	4-6-0	4 14½ × 26	6 8½	155	1599	287	2041	27	225	26,560	55·4	3500
*XIX. ...	4-6-0	2 18½ × 30	6 8½	155	1599	287	2041	27	225	25,828	54·8	3500
*XX. ..	4-4-2	2 18½ × 30	6 8½	155	1599	287	2041	27	225	25,828	39·0	3500
*XXI. ..	2-8-0	2 18½ × 30	4 7½	155	1599	287	2041	27	225	37,462	61·9	3500
†XXII. ...	4-4-0	2 18 × 30	6 8½	129	1223	215	1567	20·5	200	21,734	37·6	3500
‡XXIII. ...	4-4-2 Tank	2 18 × 30	6 8½	122	907	185	1214	20·5	195	21,190	37·0	2000
‡XXIV. ...	2-6-2 Tank	2 18 × 30	5 8	122	907	185	1214	20·5	195	25,086	54 05	2000

* As originally designed these boilers were without superheaters similar to No. 16.
† As originally designed these boilers were without superheaters similar to No. 12.
‡ As originally designed these boilers were without superheaters similar to No. 8.
§ Servé tubes.

FOUR-CYLINDER SIX-COUPLED EXPRESS LOCOMOTIVE—END VIEWS AND SECTIONS





"The Engineer" Swain Sc.

between Paddington and Bristol, taking a fast passenger train down, and returning the same day with a 70-wagon express goods train. Experimentally the engine has taken a specially made up express goods train of 70 wagons from Stoke Gifford to Swindon, and 100 wagons from Swindon to Acton at an inclusive speed of a little under 40 miles per hour.

One of our large woodcuts illustrates one of the 2-8-0 type goods engines. The Great Western Railway Company at the present time owns thirty-one of this type, and five are now being built at Swindon with superheaters. The others are being so fitted as they pass through the shops for repairs. The barrel of the boiler is 14ft. 10in. long, 4ft. 11in. diameter at the smoke-box, and 5ft. 6in. at the fire-box, which is 9ft. long. They are employed principally on the heavy mineral trains working between the following points:—Paddington and Severn Tunnel Junction, Reading and Aberdare, Salisbury and Aberdare, Bristol and Plymouth. They are also used to assist the heavy coal trains between Gowerton and Cockett over a ruling gradient of 1 in 50 for 2½ miles. The heaviest gradient worked over is 1 in 42, with a minimum load of twenty loaded 10-ton wagons, equal to about 320 tons. The average load between Swindon and Paddington is fifty-five, and maximum one hundred loaded 10-tonners, equal to about 1600 tons. The high tractive effort of 37,462 lb. and large adhesion weight of 61.9 tons enable the engines to deal with these loads with ease.

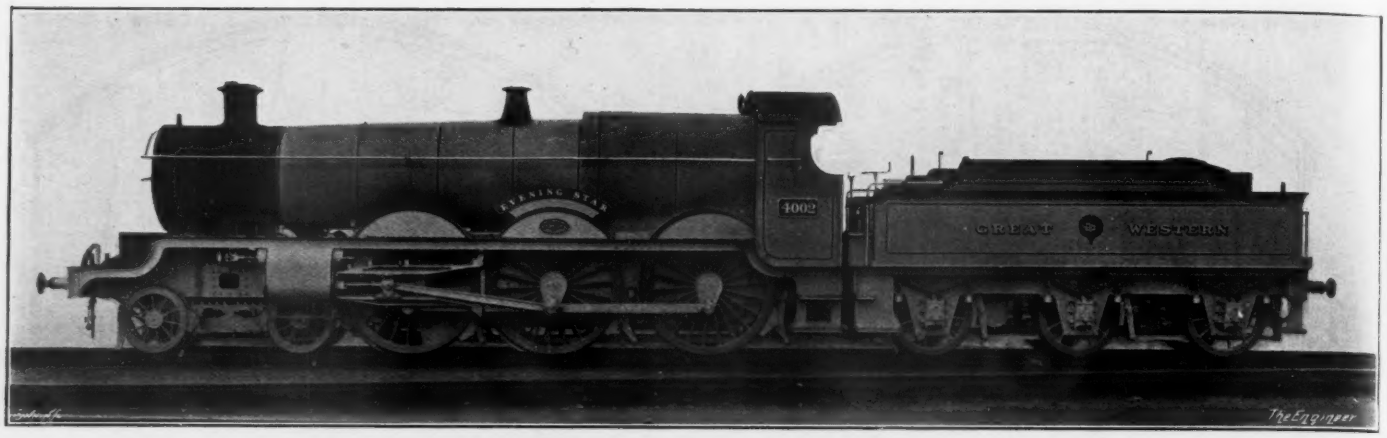


Fig. 25—FOUR-CYLINDER PASSENGER ENGINE EVENING STAR

In view of the attention now being given by engineers to the principle of superheating, it is interesting to note that all new boilers, and boilers of the standard types passing through the shops for new tube plates, are being fitted with the "Swindon" superheater. In addition to its low first cost, this apparatus has proved to be very efficient; a record of 80 engines of various classes for the five summer months of this year showed from actual results an all-round average saving of 12½ per cent. of coal, and from 25 per cent. to over 30 per cent of water.

The results show that these superheaters pay for themselves by a saving of coal in less than twelve months.

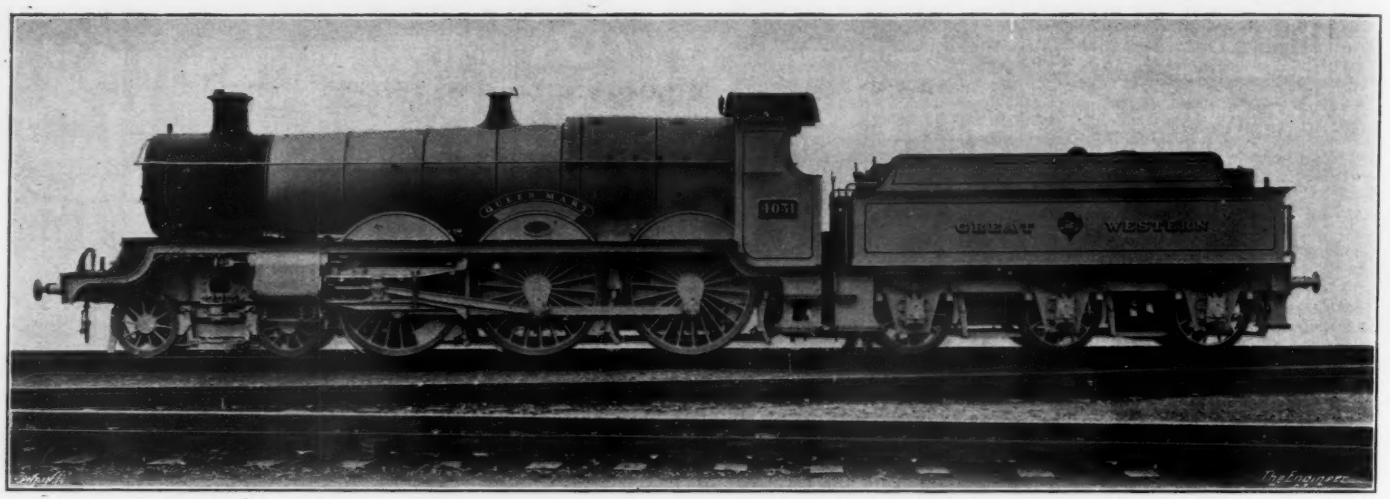


Fig. 26—FOUR-CYLINDER PASSENGER ENGINE QUEEN MARY

As will be seen from the illustration—Fig. 27—the apparatus consists of a main header A stretching across the smoke-box, a number of U-shaped junction headers B extending like fingers at the top and bottom of the main header, to which they are bolted, and a series of superheater tubes C expanded into the junction header and terminating in bends D. These tubes are stiffened by perforated plate supports E, through which they are

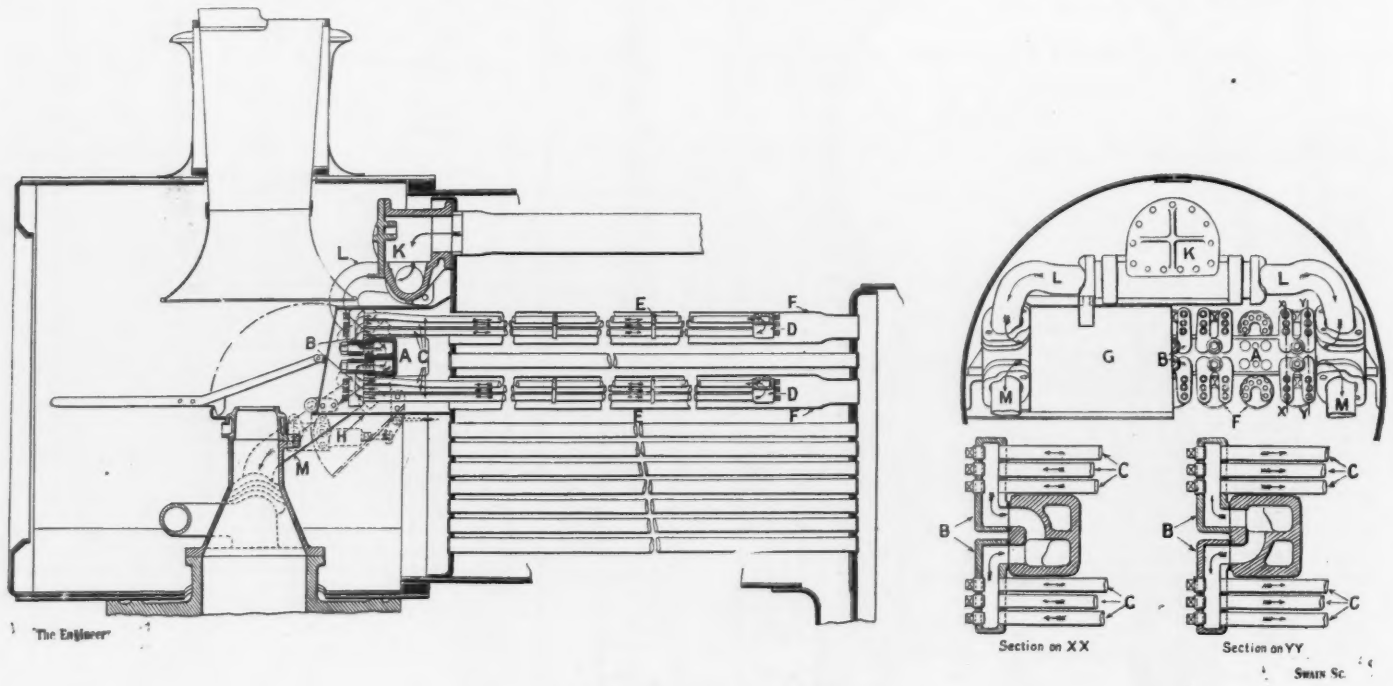


Fig. 27—THE GREAT WESTERN SUPERHEATER

passed, and project into two rows of large flues F in the boiler. The supports have the additional advantage of disturbing and "churning up" the heated gases as they pass through the flues. The whole of the smoke-box portion is enclosed by plates G. The front is hinged to give access to the superheater, and the bottom forms a damper H, the normal position of which is closed; but it is opened by a small cylinder actuated by steam, which is automatically admitted when the regulator is opened. After its production in the boiler steam passes through the regulator K and the steam pipe L to the top chamber of the main header A, thence to one finger of the junction headers B, through the small superheater tubes C, and bend D to the other finger, thence to the bottom chamber of the header and through the steam pipes M to the cylinders. The course of the steam is indicated by arrows.

Fig. 28—DYNAMOMETER CAR

In case of a failure the unit concerned can be withdrawn by removing one nut, a blank introduced on the stud, and the engine put into service again in a very short time.

It is obviously necessary in any superheater that provision should be made for keeping the flues and tubes perfectly clean, and the "horseshoe" arrangement of the small tubes in this apparatus specially lends itself to this requirement.

In our issue of December 22nd, 1905, we have already described the locomotive testing plant at Swindon, and it will be sufficient now to indicate its general features.

It is the only one existing in this country, but in its general design it resembles that at Purdue University, U.S.A. Essentially it consists of five pairs of 4ft. diameter wheels carried in bearings, which may be adjusted as to centres to suit any arrangement of wheels on a locomotive. These wheels are coupled together by a suitable arrangement of belts and jockey pulleys. The locomotive to be tested rests on these wheels, and is driven exactly as if she were running on the road. The driving wheels revolve the carrying wheels of the testing plant, and by means of the belt and pulleys the uncoupled wheels of the locomotive are revolved. A dynamometer indicates the draw-bar pull, the necessary apparatus for measuring water and coal enables careful tests to be made, and the effect of different balance weights in the wheels is obvious at once. The excess power produced is utilised by an air compressor driven from one of the shafts, which supplies compressed air for the pneumatic tools in the shop.

Two 36-ton Stothert and Pitt cranes have recently been purchased by the Great Western Railway Company for use in case of breakdowns, &c., and the illustration—Fig. 36—shows a test load in the shape of the Great Bear being lifted by the two cranes. The engine weighs 87 tons empty.

Early in 1904 the first rail motor car was built at Swindon. The cylinders are outside the frames, are 12in. diameter and 16in. stroke, and are fitted with balanced flat valves, actuated by Walschaerts valve gear. The boiler is vertical, with a cone top. The vestibule end of the car is carried on a standard carriage bogie, and the other end is carried by the engine bogie, the tractive effort of the cylinders being transmitted to the underframe of the car by means of the boiler, which acts virtually as the centre pin. The Great Western Railway Company at the present time possesses 100 of these cars, fifty 70ft. long, and forty-seven 59ft. 6in. long over the headstocks; and three other cars, one of which was taken over from the Port Talbot Railway Company, and the others purchased from a private firm. With the exception of the latter three all the cars were built at Swindon, and have the same size engines and boilers, which are interchangeable throughout. The cars, Fig. 35, are used with and without trailers attached on all portions of the line. In a "shuttle" service the car can be driven from the engine end, or from the other end of the trailer as desired. The diagrams, page xix., give full particulars of the engine and car.

During the last two years the small 0-4-2 and 0-6-0 side tank engines, Fig. 33, of which the company possesses a great number, have been utilised for this car service. The engine is fitted with a special regulator gear, similar to that of the motor engines, which enables it to be driven from the trailer end. For the motor car service at Plymouth the idea has been further developed, and at certain times, when the traffic is particularly heavy, four 70ft. cars are run with the engine in the middle. In this case it is driven from either end of the train as desired.

Mention has already been made in reference to an old time-table of 1840 of the coaching stock in use in early times. We show, Fig. 30, an old broad gauge four-wheel first-class coach with luggage rack on top. It will be seen that the sides are panelled in the style of an old stage coach. In 1838 these carriages were 24ft. long and 9ft. wide. They carried twenty-four passengers, and weighed 4 tons 14 cwt. The six-wheel first-class carried thirty-two passengers, and weighed 6 tons 11 cwt. The illustration, Fig. 31, of the old broad gauge third-class carriage shows it as being originally built open, but the top appears to have been added at a later date; 4ft. diameter wheels were used under all coaches.

The illustration, Fig. 32, shows the original Queen's saloon used by Queen Victoria on her first railway journeys between Paddington and Windsor. The saloon had wooden wheels and wooden tires, with the idea of deadening the noise when running. It was built in 1840, was 21ft. long and 9ft. wide, and had three compartments, the two end ones being 4ft. 6in. long.

On page xix. we show in diagram form—see Fig. 34—some of the recent stock built at Swindon, which is interesting when compared with the old broad gauge stock illustrated above. These show a first-class carriage used on the Fishguard service. It weighs 34 tons and seats 48 passengers. A third-class used on the same service, which weighs 33 tons 11 cwt., and seats 80 passengers; a stowage van for the same service, which weighs 31 tons 8 cwt., and carries 20 tons; a dining and restaurant car, with kitchen at one end. It weighs 35 tons 16 cwt., and seats 42; and a sleeping car fitted up with a lavatory at each end, attendant's compartment, and accommodation for 12 sleepers. The car weighs 41 tons 16 cwt. All these carriages are 70ft. long over mouldings and 9ft. wide.

The deleterious effects produced by certain qualities of water on the boiler of a locomotive are well known, and the varying degrees of hardness of water in different districts are a source of continual trouble to a locomotive engineer. To obviate this as far as possible, the Great Western Railway Company has installed water softening plants where necessary in connection with the water troughs and water cranes. They vary in capacity, and the following list shows the places at which they are placed:—

Place.	Capacity. Gals. per hour.
1. Aldermaston	10,000
2. Foxes Wood (near Bristol)	20,000
3. Goring (between Reading and Didcot)	20,000
4. Severn Tunnel Junction	30,000
5. Reading	15,000
6. Southall	10,000
7. Southcote Junction	500
8. Sudbrook	30,000

It would not be right to conclude this section without saying one word about the engines taken over by the Great Western Railway from the South Devon Railway. They were all tank engines. They were named and bore no numbers until the amalgamation, when they received Great Western Railway numbers. They were built principally by the Avonside Company at Bristol, but a small proportion had been originally purchased from the Great Western Railway Company. The illustration, Fig. 17, page ix., shows a typical "South Devon Broad Gauge Tank," originally named Etna. The engine had 17in. by 24in. cylinders, four 5ft. 6in. coupled wheels, and a leading bogie. The boiler had a working pressure of 120 lb. per square inch. The engines were very successful in dealing with the fast trains on the heavy gradients and curves of the South Devon Railway. For goods traffic six coupled tank engines were used with the same size cylinders, driving wheels 4ft. 6in. diameter, and a similar boiler to the 4-4-0 tanks. Several of the engines were cut up, or used as stationary engines, at the amalgama-

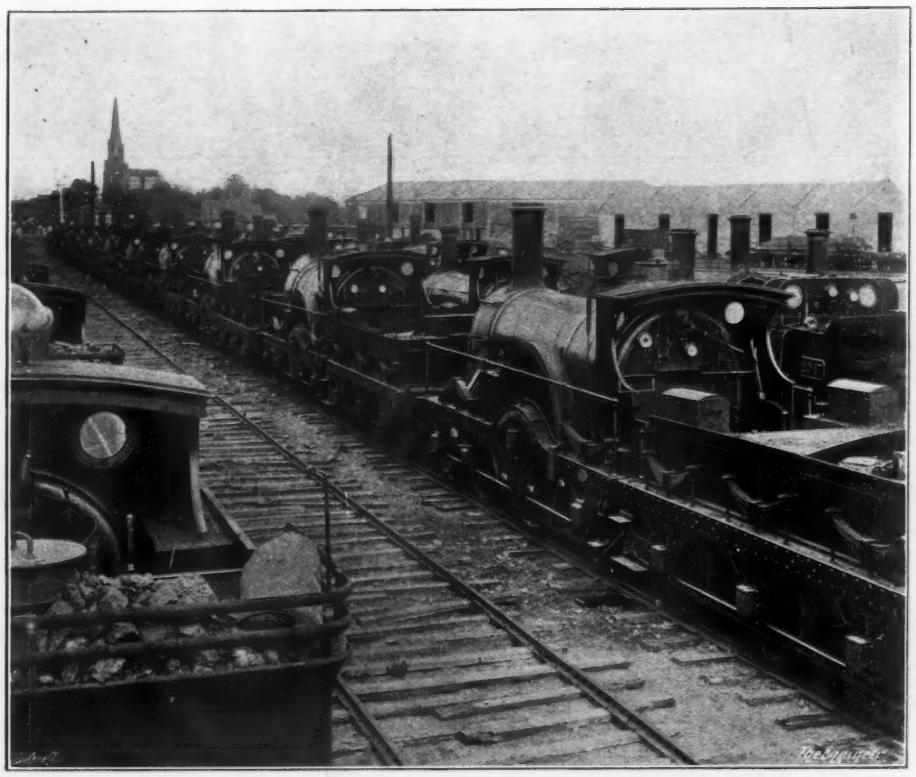


Fig. 29—BROAD GAUGE ENGINES ON SPECIAL SIDINGS

BROAD GAUGE ROLLING STOCK

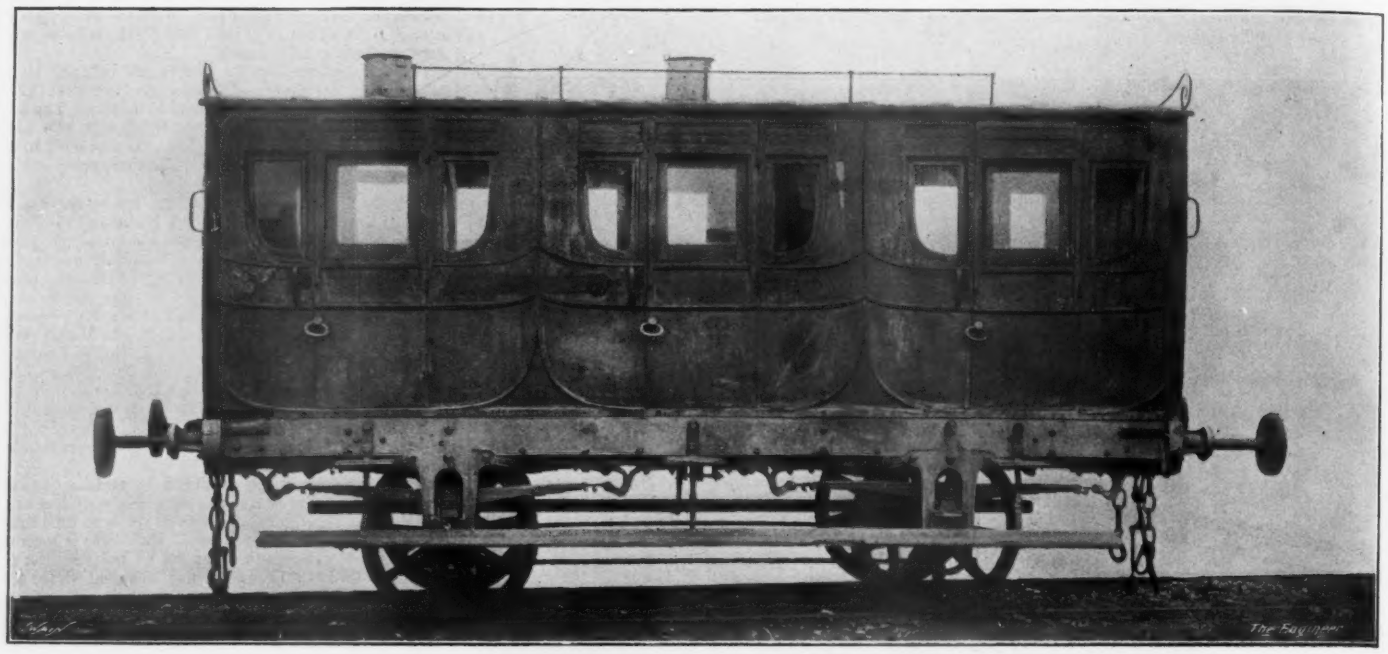


Fig. 30—OLD BROAD GAUGE FIRST-CLASS COACH

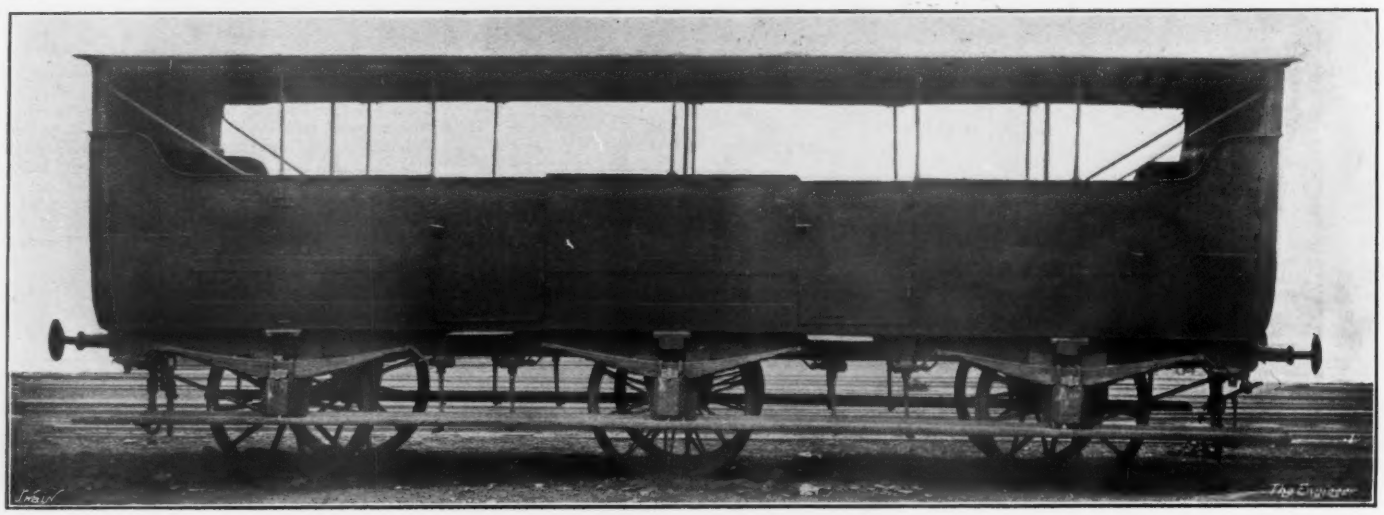


Fig. 31—QLD BROAD GAUGE THIRD-CLASS COACH

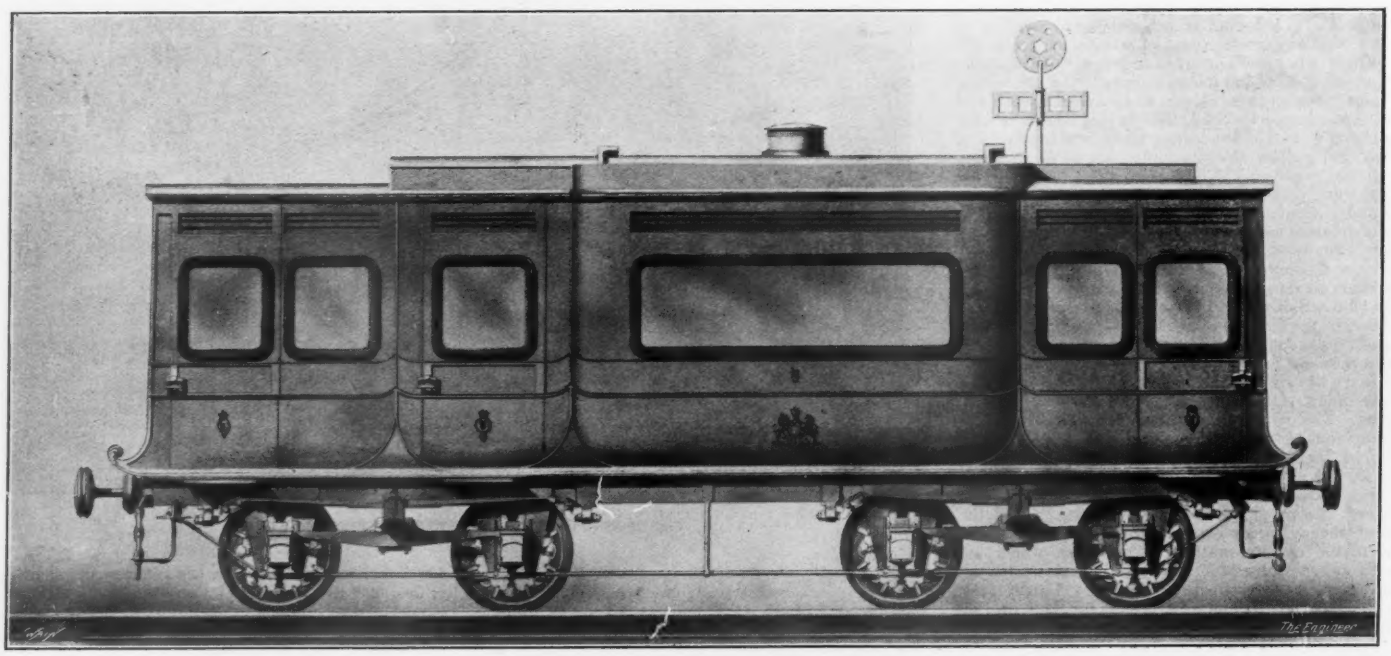


Fig. 32—QUEEN VICTORIA'S BROAD GAUGE COACH

tion, but the majority continued to run until the alteration of the gauge in 1892.

THE BROAD GAUGE LOCOMOTIVES OF THE GREAT WESTERN RAILWAY.

EIGHTEEN years ago, in the course of an article dealing with the conversion of gauge on the Great Western Railway,* we had to confess that "nothing is more difficult than the writing of accurate history." We were then confronted with conflicting evidence as to the early locomotives of this railway, which seemed well nigh impossible of reconciliation, and it must be admitted that a discussion which started in our columns a few years later, so far from clearing up matters then in doubt, rather rendered confusion worse confounded, since the evidences then brought forward failed in several important details to agree with contemporary records.

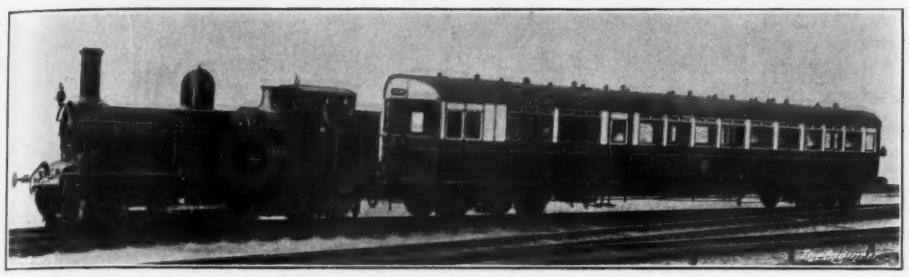


Fig. 33—AUTO-ENGINE AND TRAILER

Without any intention of reviving questions involved in that dispute, we here place on record what we believe to be an accurate account of the early locomotive history of the line. Subsequently to 1840, when Mr. Gooch made an attempt at the provision of standard types, there is abundant evidence to work from. But for the period from 1837 to that date there is no official record, and, consequently, the compilation of that part of the history is a matter of weighing evidence. For this purpose the authorities consulted are Nicholas Wood's work on "The Railways of Great Britain and Ireland" (dated 1840), the evidence of witnesses before the Gauge Commissioners in 1845, and "The Diaries of Sir Daniel Gooch, Bart." (published in 1892). Invaluable contributory evidence has been afforded by two officials of the locomotive department, who had a propensity for taking elaborate notes of the engines passing through their hands, one of these now deceased gentlemen having sketched and measured almost every type of engine existing prior to 1849, and the other continuing the record to a later date. The note-books containing these sketches came into the hands of an impartial investigator, who contributed to our contemporary, the *Locomotive Magazine*, a series of articles embodying the information thus acquired, and it is to that investigator, Mr. Geo. Fredk. Bird, and to the publishers of that magazine, that we are indebted for the subjoined particulars, and for the reproduction of some of the more interesting of the drawings illustrating the historical articles referred to. We may say that Mr. Bird has given us documentary proof of the authenticity of his drawings, and we are convinced of his impartial desire to set out the bare facts of history.

Limitations of space will only permit of a passing reference to the various engines illustrated by the line drawings on pages xx. and xxi. Though not actually the first engine to be in steam on the railway, undoubtedly the most interesting of the early engines of the Great Western Railway was North Star, shown in Fig. 1. That engine, and Morning Star—Fig. 2—were built by R. Stephenson and Co. for the New Orleans Railway Company, to the 5ft. 6in. gauge, and were actually shipped to New York, but owing to financial troubles they were brought back, and were subsequently adapted to the 7ft. gauge of the Great Western Railway. Fig. 1 shows the North Star as it first ran on that railway, though it was better known in the rebuilt condition* in which it existed until a year or two ago, when, after vainly trying to find it a home at South Kensington, the railway officials had reluctantly to break it up. The Morning Star was altogether a smaller engine.

The first engine actually delivered to the railway was the Vulcan—Fig. 3—built by Charles Tayleur and Co., of the Vulcan Foundry, Newton-le-Willows. Five somewhat similar engines were supplied by the same firm, but, as in the case of all makers at that early date, there was no such thing as a standard pattern, and they differed in appearance and dimensions one from another. Three of the six were afterwards rebuilt with smaller wheels, as shown in Fig. 4, and all were converted later into tank engines.* Mather, Dixon and Co. built six engines for the Great Western Railway—two as shown in Fig. 5, two with larger driving wheels but of the same general design, and two remarkable machines, one of which is shown in Fig. 6. These last had 10ft. driving wheels; and in this connection it may be mentioned that a sketch in one of the note-books already referred to establishes the fact of the existence of these huge wheels beyond the shadow of a doubt; this sketch of the complete engine being further confirmed by another showing the boiler, cylinders, and part of the frame as subsequently adapted for stationary work. Sharp, Roberts and Co. contributed three engines to the early stock of the railway, shown in Fig. 7. The disposition of the wheels in these engines was quite distinct from the firm's practice on the narrow gauge. The Haigh Foundry Company, of Wigan, built two engines of a remarkable nature, having 6ft. driving wheels, which, by the interposition of spur and pinion gearing between the cylinders and the wheels, in the ratio of 1 : 2, gave the effect of 12ft. wheels. Unfortunately, no drawing is available of the engines as originally built, but this is the less regrettable, as they apparently were absolute failures, and were subsequently rebuilt in the form shown in Fig. 8. Two still more remarkable engines were built by R. and W. Hawthorn, in accordance with T. E. Harrison's patents, the boiler being mounted on a carriage separate from that which contained the cylinders and driving gear. One of these engines had single driving wheels of 10ft. diameter, the other had four-

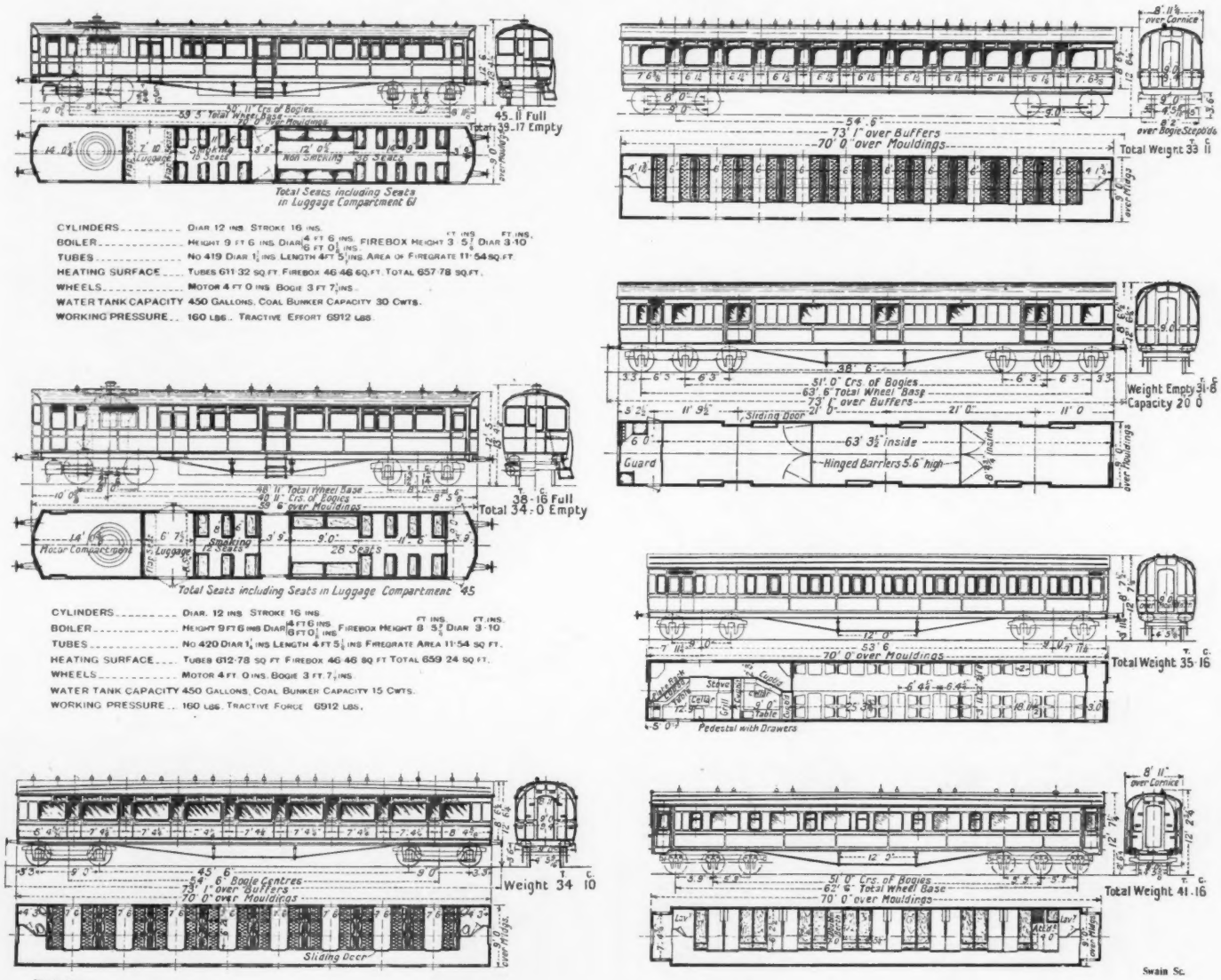

CYLINDERS ... Diar 12 ins Stroke 16 ins.
BOILER ... Height 9 ft 6 ins Diar 4 ft 6 ins / 6 ft 0½ ins Firebox Height 3 ft 5⅞ ins Diar 3 ft 10 ins
TUBES ... No 419 Diar 1¾ ins Length 4 ft 5⅛ ins Area of Firegrate 11·54 sq ft
HEATING SURFACE ... Tubes 611·32 sq ft Firebox 46·46 sq ft Total 657·78 sq ft.
WHEELS ... Motor 4 ft 0 ins Bogie 3 ft 7½ ins
WATER TANK CAPACITY 450 Gallons. Coal Bunker Capacity 30 Cwts.
WORKING PRESSURE ... 160 lbs. Tractive Effort 6912 lbs.
Total Seats including Seats in Luggage Compartment 61
Total 39·17 Empty
45·11 Full
Total Weight 33 11
Weight Empty 31·8
Capacity 20 0
Total 34·0 Empty
38·16 Full
Total Seats including Seats in Luggage Compartment 45
CYLINDERS ... Diar. 12 ins Stroke 16 ins
BOILER ... Height 9 ft 6 ins Diar 4 ft 6 ins / 6 ft 0½ ins Firebox Height 3 ft 5⅞ ins Diar 3 ft 10 ins
TUBES ... No 420 Diar 1¾ ins Length 4 ft 5⅛ ins Firegrate Area 11·54 sq ft.
HEATING SURFACE ... Tubes 612·78 sq ft Firebox 46·46 sq ft Total 659·24 sq ft.
WHEELS ... Motor 4 ft. 0 ins. Bogie 3 ft 7½ ins.
WATER TANK CAPACITY 450 Gallons. Coal Bunker Capacity 15 Cwts.
WORKING PRESSURE ... 160 lbs. Tractive Force 6912 lbs.
Weight 34 10
Total Weight 35 16
Total Weight 41 16
Pedestal with Drawers
Sliding Door
Swain Sc.
The Engineer

Fig. 34—MODERN PASSENGER ROLLING STOCK

* THE ENGINEER, May 13th, 20th, 27th, 1892.

* THE ENGINEER, May 27th, 1892, page 456.

* THE ENGINEER, October 11th, 1895, page 355.

† THE ENGINEER, September 13th, 1895, page 249, and October 11th, 1895, page 355.

BROAD GAUGE LOCOMOTIVES OF THE GREAT WESTERN RAILWAY

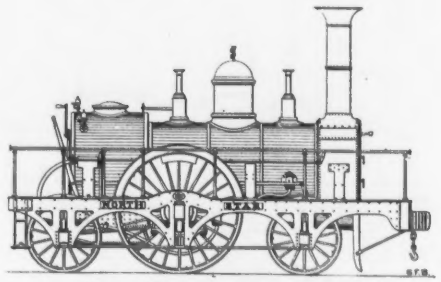


Fig. 1. "North Star." 1837.

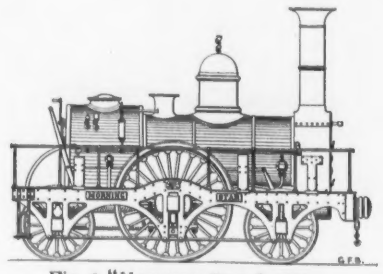


Fig. 2. "Morning Star." 1838.

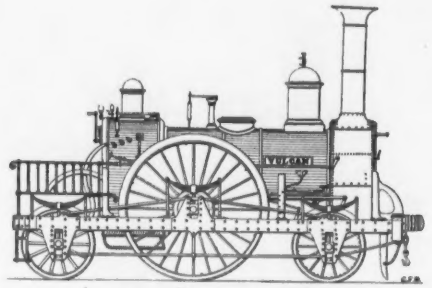


Fig. 3. "Vulcan." 1837.

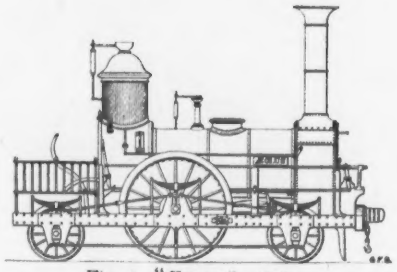


Fig. 4. "Æolus" 1838.

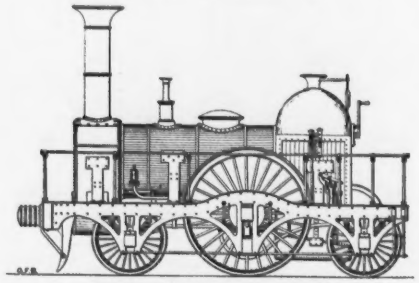


Fig. 5. "Premier." 1838.

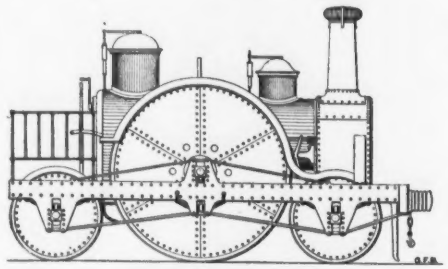


Fig. 6. "Ajax." 1838.

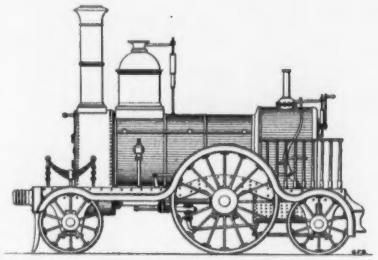


Fig. 7. "Lion" 1838.

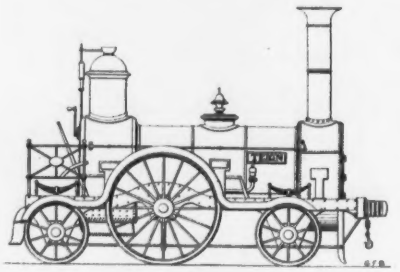


Fig. 8. "Teign."

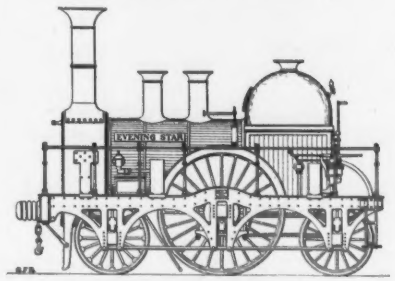


Fig. 9. "Evening Star." 1839.

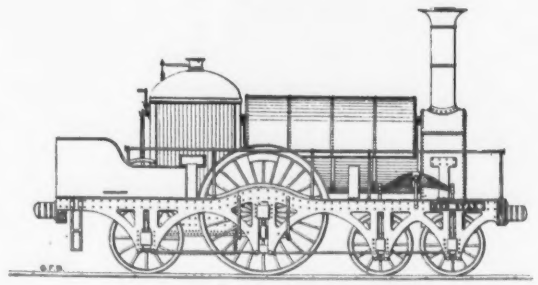


Fig. 10. "Red Star." Rebuilt.

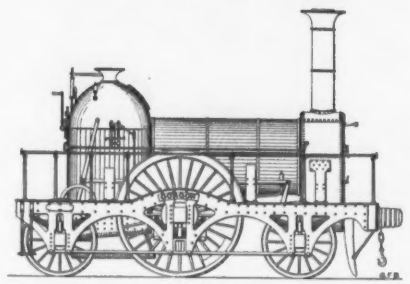


Fig. 11. "Gorgon." 1841.

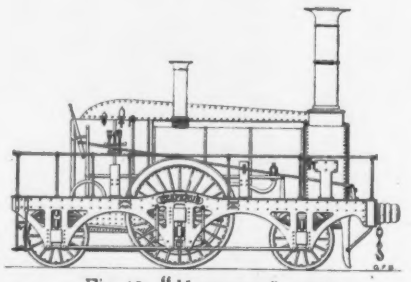


Fig. 12. "Hesperus" 1841.

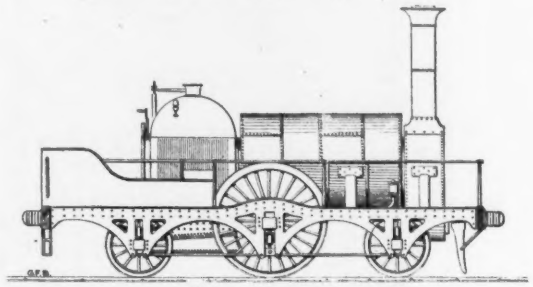


Fig. 13. "Sun" Class. Rebuilt.

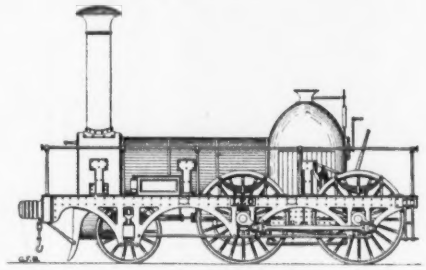


Fig. 14. "Leo." 1841.

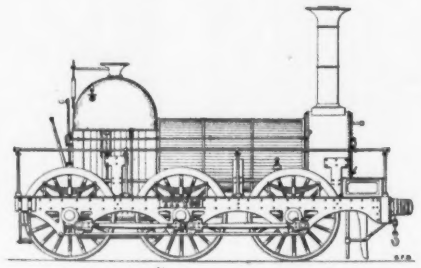


Fig. 15. "Tityos." 1842.

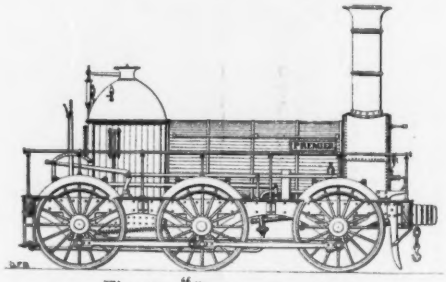


Fig. 16. "Premier." 1846.

The Engineer

Swain Sc.

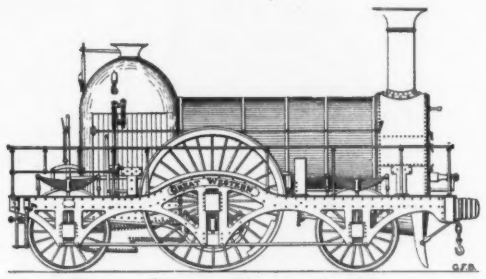


Fig. 17. "GREAT WESTERN." 1846.

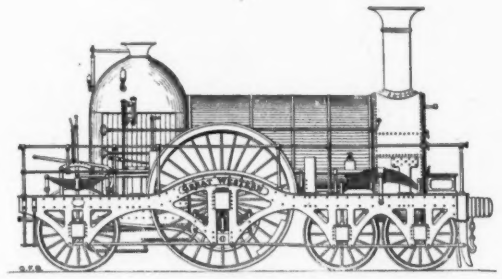


Fig. 18. "GREAT WESTERN" Rebuilt.

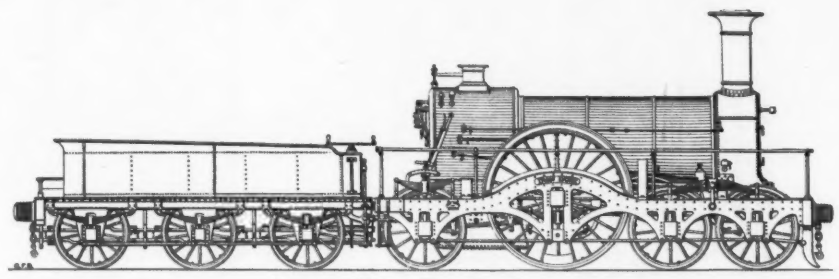


Fig. 19. "IRON DUKE." 1847.

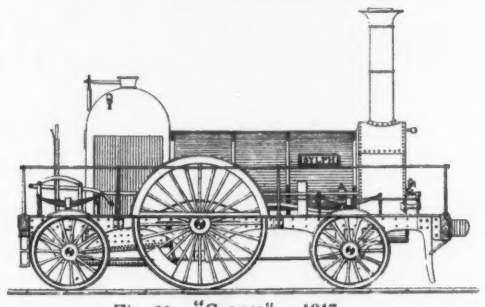


Fig. 20. "SYLPH." 1847.

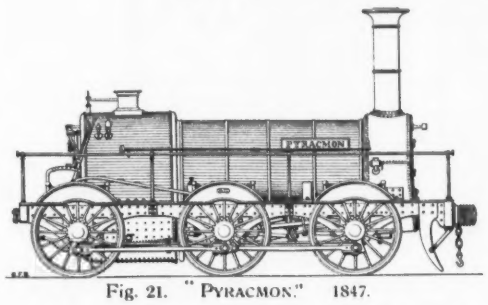


Fig. 21. "PYRACMON." 1847.

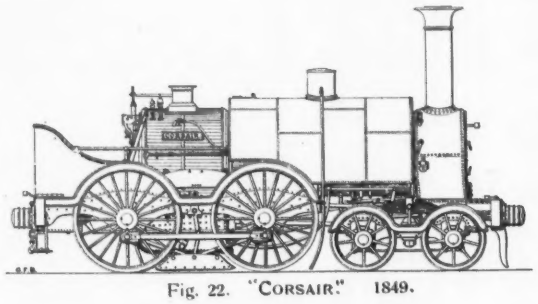


Fig. 22. "CORSAIR." 1849.

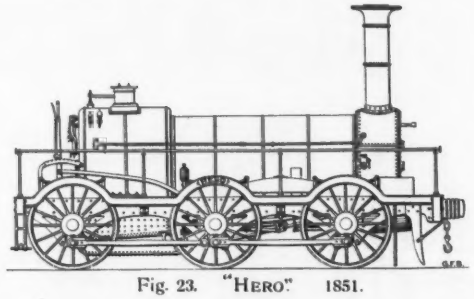


Fig. 23. "HERO." 1851.

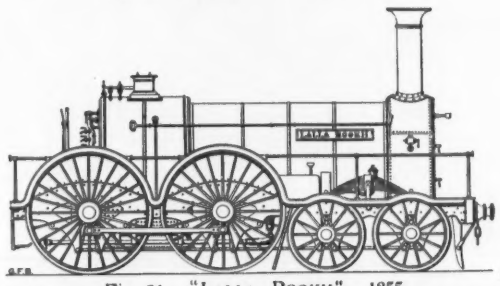


Fig. 24. "LALLA ROOKH." 1855.

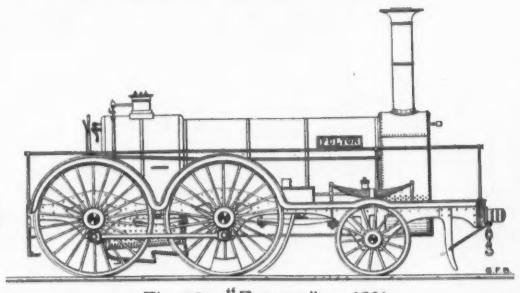


Fig. 25. "FULTON." 1864.

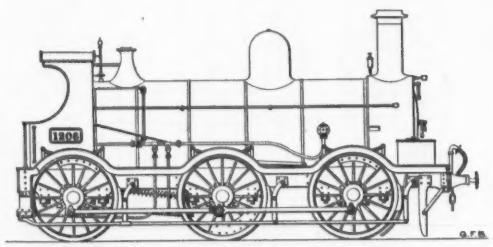


Fig. 26. Nos. 1206-1215.

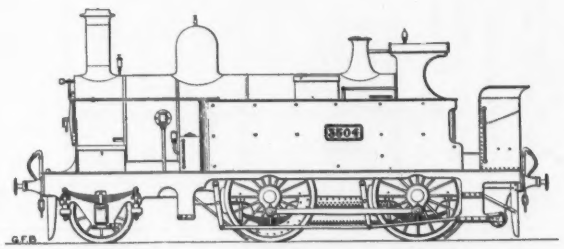


Fig. 27. Nos. 3501-3510. 1885.

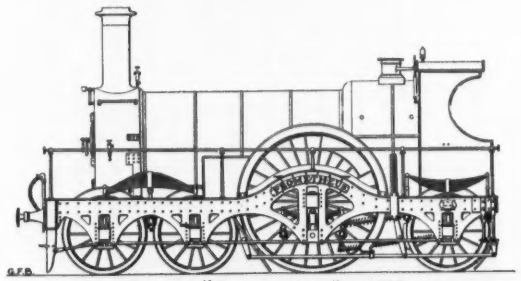


Fig. 28. "PROMETHEUS." 1888.

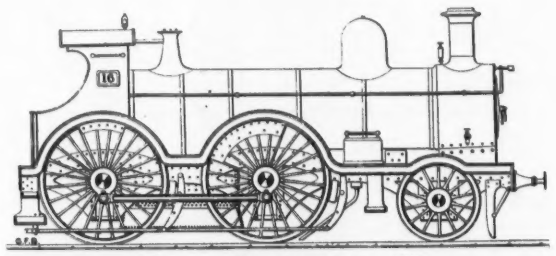


Fig. 29. Nos. 14 and 16. 1888.

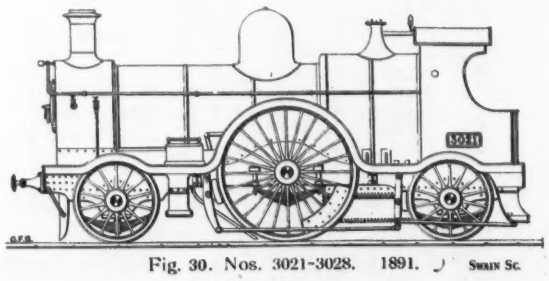


Fig. 30. Nos. 3021-3028. 1891.

BROAD GAUGE LOCOMOTIVES, GREAT WESTERN RAILWAY

(See Diagrams on pages xx. and xxi.)

"STAR" CLASS. Figs. 1, 2, 9, and 10.

Built by R. Stephenson and Co., 1837—1841.

North Star	Dog Star	Lode Star	Shooting Star*
Morning Star*	Polar Star*	Rising Star*	Western Star
Evening Star	Red Star*	Bright Star*	Royal Star

* Rebuilt as 8-wheel Saddle Tanks, Fig. 10.

"VULCAN" CLASS. Figs. 3 and 4.

Built by Chas. Tayleur and Co., 1837—1838.

Vulcan Æolus Bacchus Apollo Neptune Venus (1)

"PREMIER" CLASS. Fig. 5.

Built by Mather Dixon and Co., 1838.

Premier (1) Ariel Planet Mercury (1)

"AJAX" CLASS. Fig. 6.

Built by Mather Dixon and Co., 1838.

Ajax (1) Mars (1)

"LION" CLASS. Fig. 7.

Built by Sharp, Roberts and Co., 1838.

Lion Atlas Eagle

"SNAKE" CLASS.

Built by the Haigh Foundry Company, 1838.

Snake Viper

Afterwards rebuilt as Teign and Exe. Fig 8.

"THUNDERER" CLASS.

Built by R. and W. Hawthorn, 1838.

Thunderer Hurricane

"FIRE FLY" CLASS. Fig. 11.

Built by Jones, Turner and Evans, 1840.

Fire Fly	Wild Fire	Fire King*	Fire Brand
Spit Fire	Fire Ball*		

* Rebuilt as 6ft. Saddle Tanks, Fig. 13.

Built by Sharp, Roberts and Co, 1840—1841.

Tiger	Lynx	Hawk	Ostrich
Leopard	Stag	Falcon	Greyhound
Panther	Vulture		

Built by Fenton, Murray and Jackson, 1840-1842.

Charon	Minos	Acheron	Phlegethon
Cerberus	Ixion	Erebus	Medusa
Cyclops	Gorgon *	Medea	Proserpine
Pluto	Hecate	Hydra	Ganymede
Harpy	Vesta	Lethe	Argus

Built by Longridge and Co., 1841.

Jupiter	Mars (2)	Venus (2)	Mercury (2)
Saturn	Lucifer		

Built by Nasmyth, Gaskell and Co., 1841—1842.

Achilles	Mentor	Orion*	Pollux
Milo	Bellona	Damon	Phœnix
Hector	Actæon	Electra	Pegasus
Castor	Centaur	Priam	Stentor

* Rebuilt as 8-wheel Saddle Tank, Fig. 10.

Built by Slaughter and Co., 1841.

Arrow Dart

Built by G. and J. Rennie, 1841.

Mazeppa Arab

"SUN" CLASS. Figs. 12 and 13.

Built by R. and W. Hawthorn, 1840—1841.

Sun	Meridian	Comet	Aurora
Sunbeam	Eclipse	Meteor	Hesperus*

* Fitted with return-tube boiler, Fig. 12.

Built by Sharp, Roberts and Co., 1841.

Gazelle Giraffe Antelope Wolf Zebra

Built by Slaughter and Co., 1841—1842.

Javelin	Yataghan	Assegai	Stiletto
Djerid	Lance	Rocket	Creese

"Sun" Class all rebuilt as Saddle Tanks, Fig. 13.

"ELEPHANT" CLASS. Fig. 14.

Built by R. and W. Hawthorn, 1841.

Elephant Buffalo Dromedary

Built by Fenton, Murray and Jackson, 1841.

Hecla Stromboli Etna

Built by Rothwell and Co., 1841—1842.

Aries	Cancer	Libra	Capricornus
Taurus	Leo	Scorpio	Aquarius
Gemini	Virgo	Sagittarius	Pisces

"HERCULES" CLASS. Fig. 15.

Built by Nasmyth, Gaskell and Co., 1842.

Hercules Samson Goliath Tityos

"BANKING" CLASS. SADDLE TANK.

Built by Slaughter and Co., 1846.

Avalanche

"GREAT WESTERN" CLASS. Figs. 17 and 18.

Built by Great Western Railway Company, 1846.

Great Western

"PREMIER" CLASS (1st lot). GOODS ENGINES. Fig. 16.

Built by Great Western Railway Company, 1846—1847.

Premier (2)	Bellerophon	Dreadnought	Briareus
Ajax (2)	Vesuvius	Fury	Brontes
Argo	Telica	Bergion	Jason

"ELK" CLASS. Fig. 20.

Built by Great Western Railway Company, 1847.

Elk Prince Peri Witch Queen Sylph

"IRON DUKE" CLASS. Fig. 19.

Built by Great Western Railway Company, 1847.

Iron Duke	Great Britain	Pasha
Lightning	Emperor	Sultan

"PYRACMON" CLASS (2nd lot). GOODS ENGINES. Fig. 21.

Built by Great Western Railway Company, 1847—1848.

Pyracmon	Mammoth	Alligator
Caliban	Behemoth	Steropes

"COURIER" CLASS.

Built by Great Western Railway Company, 1848—1851.

Courier	Wizard	Swallow	Estaffete
Tartar	Rougemont	Timour	Rover
Dragon	Hirondelle	Prometheus	Amazon
Warlock	Tornado	Perseus	Lord of the Isles

"CORSAIR" CLASS. Fig. 22.

Built by Great Western Railway Company, 1849.

Corsair Brigand

"DIDO" CLASS (3rd lot). GOODS ENGINES. Fig. 23.

Built by Great Western Railway Company, 1851.

Dido	Hero	Nora Creina	Cæsar
Druid	Florence	Volcano	Thunderer

"GIAOUR" CLASS (4th lot). GOODS ENGINES.

Built by Great Western Railway Company, 1852.

Giaour Hebe Flirt Pearl

"ARIADNE" CLASS (5th lot). GOODS ENGINES.

Built by Great Western Railway Company, 1852—1854.

Ariadne	Ulysses	Coquette	Monarch
Leander	Cicero	Hecuba	Zina
Europa	Diana	Wellington	Ceres
Cato	Minerva	Romulus	Brutus
Nelson	Psyche	Remus	Ruby
Trafalgar	Cupid		

"JUNO" CLASS. SADDLE TANKS.

Built by Great Western Railway Company, 1852—1854.

Juno Iago Plato Bithon

"SAPPHO" CLASS. BOGIE TANKS.

Built by Great Western Railway Company, 1854—1855.

Sappho	Ovid	Lucretius	Euripides
Homer	Juvenal	Theocritus	Hesiod
Virgil	Seneca	Statius	Lucan
Horace			

"FLORA" CLASS (6th lot). GOODS ENGINES.

Built by Great Western Railway Company, 1854—1856.

Flora	Vixen	Nemesis	Osiris
Thames	Sibyl	Nero	Pelops
Vesper	Sphinx	Plutus	Creon
Iris	Salus	Zetes	Panthea
Neptune	Banshee	Octavia	Amphion
Cyprus	Cambyses	Metis	Magi
Janus	Midas	Rhea	Pallas
Caliph	Nimrod	Typhon	Gyfeillon
Orson	Geryon		

Built by Great Western Railway Company, 1857.

Mersey	Tweed	Esk	Liffey
Severn	Humber	Avon	

Built by Great Western Railway Company, 1858—1863.

Warrior	Tay	Wye	Severus
Warhawk	Forth	Wear	Theseus
Pioneer	Tyne	Plym	Pandora
Champion	Xerxes	Talbot	Chronos
Luna	Lagoon	Plutarch	Scylla
Ethon	Hades	Gladiator	Cossack
Boyne	Olympus	Sirius	Tantalus
Shannon	Regulus	Orpheus	Leonidas
Rhondda			

Built by Great Western Railway Company, 1864.

Swindon	Bristol	Windsor	Bath
London	Chester	Shrewsbury	Wolverhampton
Reading	Oxford	Newport	Birmingham

"ALMA" CLASS.

Built by Rothwell and Co., 1854—1855.

Alma	Inkerman	Crimea	Sebastopol
Balaclava	Kertch	Eupatoria	

"LALLA ROOKH" CLASS. Fig. 24.

Built by R. Stephenson and Co., 1855.

Lalla Rookh	Rob Roy	Pirate	Red Gauntlet
Ivanhoe	Waverley	Abbot	Antiquary
Robin Hood	Cœur de Lion		

"VICTORIA" CLASS.

Built by Great Western Railway Company, 1856.

Victoria	Oscar	Victor	Alexander
Napoleon	Abdul Medjid	Emmanuel	Otho
Leopold			

"BRUNEL" CLASS. Fig. 25.

Built by Great Western Railway Company, 1863—1864.

Brunel	Trevithick	Fulton *	Rennie
Locke	Smeaton	Telford	Brindley
Stephenson	Watt		

"BEE" CLASS. METROPOLITAN TANKS.

Built by Vulcan Foundry Company, 1862.

Bee	Wasp	Hornet	Gnat
Locust	Mosquito		

Built by Kitson and Co., 1863.

Khan	Czar	Shah	Bey
Kaiser	Mogul		

Built by Great Western Railway Company, 1863—1864.

Fleur-de-Lis	Shamrock	Lily	Violet
Rose	Camelia	Myrtle	Laurel
Thistle	Azalea		

"HAWK" CLASS. REBUILDS.

Built by Great Western Railway Company, 1865—1866.

Hawk	Phlegethon	Acheron	Pollux*
Ostrich*	Cerberus*		

* Afterwards converted into Tank Locomotives.

"HAWTHORN" CLASS.

Built by Avonside Engine Company, 1865—1866.

Hawthorn	Gooch	Dewrance	Penn*
Hackworth	Roberts	Forster	Stewart
Murdoch	Hedley*	Avonside	Peacock
Melling*	Fenton	Blenkensop	Sharp
John Gray	Bury*	Beyer*	Wood

* Afterwards converted into Tank Locomotives.

"SIR WATKIN" CLASS. SADDLE TANKS.

Built by Great Western Railway Company, 1866.

Sir Watkin	Whetham	Saunders*	Miles
Bulkeley*	Fowler*		

* Handed over to South Devon Railway; afterwards Nos. 2157—

"LIGHTNING" CLASS. Fig. 23.

Built by Great Western Railway Company, 1878.

Lightning	Crimea	Inkerman	Courier
Amazon	Eupatoria		

Built by Great Western Railway Company, 1880.

Bulkeley	Emperor	Sebastopol	Alma
Dragon	Great Britain		

Built by Great Western Railway Company, 1888.

Great Western Prometheus Tornado

No. 1206 CLASS. Fig. 26.

Built by Great Western Railway Company, 1883—1884.

Nos. 1196–1205. Originally built for normal gauge
Nos. 1206–1213. Afterwards converted to normal gauge

No. 1228 CLASS. SADDLE TANKS.

Built by Great Western Railway Company, 1883—1884.

Nos. 1228–1237. Afterwards converted to normal gauge
Nos. 1238–1257. Originally built for normal gauge

No. 3501 CLASS. Fig. 27.

Built by Great Western Railway Company, 1885.

Nos. 3501–3510. Afterwards converted to normal gauge, and still later rebuilt as tender engines

No. 8 CLASS. FOUR-CYLINDER COMPOUND.

Built by Great Western Railway Company.

No. 8. Subsequently rebuilt as No. 8 "Gooch," for normal gauge

No. 14 CLASS. Fig. 29.

Built by Great Western Railway Company, 1888.

Nos. 14 and 16. Afterwards converted to normal gauge and rebuilt as Charles Saunders and Brunel

No. 3541 CLASS. TRAILING BOGIE TANKS.

Built by Great Western Railway Company.

Nos. 3541–3560. Afterwards converted to normal gauge

No. 3021 CLASS. Fig. 30.

Built by Great Western Railway Company, 1891.

Nos. 3021–3028. Afterwards converted to normal gauge, and still later rebuilt with leading bogies, and named:—

Wigmore Castle	St. George
Rougemont (afterwards Bessemer)	Tornado
Swallow	Thames (afterwards Worcester)
Storm King	Wellington

BROAD GAUGE ENGINES OF THE GREAT WESTERN RAILWAY

Leading Dimensions of Locomotives Illustrated in Figs. 1-30 (*pages* xx. *and* xxi.).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cylinders, diameter, in.	16	16	14	14	14	14	14	14¾	15	15	15	15	15	15	16
,, stroke, in.	16	16	16	16	14	20	18	18	18	18	18	18	18	18	18
Driving wheels, diameter, ft.	7	6½	8	6	7	10	6	6½	7	7	7	6	6	5	5
Carrying wheels, diameter, ft.	4	4	4	3	4	5	3½	3½	4	3½ & 4	4	3½	3½	3½	5
Wheel base, ft.	13⅛	12½	15	13⅛	13	15½	13⅝	13	12 5/16	17	13½	13¾	13¾	12⅝	12½
Heating surface, fire-box, sq. ft.	66·62	68·42	57·15	57·15	51·71	57·3	51·17	47·17	68·91	93·81	90·6	70·42	90·34	66·6	—
,, ,, tubes, sq. ft.	639·94	647·60	529·78	529·78	325·63	416·7	427·50	439·00	569·06	724·16	537·0	546·96	551·92	401·4	—
,, ,, total, sq. ft.	706·56	716·02	586·93	586·93	377·34	474	478·67	486·17	637·97	817·97	647·6	617·38	642·26	468·0	—
Grate area, sq. ft.	—	—	—	—	—	10·22	11·66	—	14·14	—	12·57	—	11·68	11·47	—
Weight, tons	18·25	12·625	—	—	—	—	16 E	—	—	32	24·2	—	25·375	—	—

Leading Dimensions of Locomotives Illustrated in Figs. 1-30 (*pages* xx. *and* xxi.) (*continued*).

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Cylinders, diameter, in.	16	18	18	18	16	16	17	17	17	16	17	17	18	20	20
,, stroke, in.	24	24	24	24	24	24	24	24	24	24	24	26	24	24	24
Driving wheels, diameter, ft.	5	8	8	8	7	5	6	5	7	6½	5	5 1/12	8	7	7ft. 8½in.
Carrying wheels, diameter, ft.	5	4½	4 & 4½	4½	4	5	3½	5	4½	4	5	3½	4½	4½	4ft 7½in.
Wheel base, ft.	14½	16	18 5/12	18 1/12	14½	15 5/12	18⅛	15½	17ft. 1½in.	15½	15½	17½	19	18½	18½
Heating surface, fire-box, sq. ft.	105·91	151·05	151·05	147·87	111·68	126·31	—	126·31	129·8	118·62	—	103·29	137·0	—	124·0
,, ,, tubes, sq. ft.	876·27	1582·16	1582·16	1797·12	954·82	1236·83	—	1236·83	1444·2	1145·25	—	1106·57	1947·7	—	1321·0
,, ,, total, sq. ft.	982·18	1733·21	1733·21	1944·99	1066·50	1363·14	—	1363·14	1574·0	1263·17	—	1209·86	2084·7	—	1445·0
Grate area, sq. ft.	13·67	22·64	22·64	21·66	13·67	18·44	19	18·44	19·2	13·5	—	16·2	—	—	20·8
Weight, tons	28·75	29 E	—	35½	25·85	28·15	35·75	32·475	36·675	30·65	—	44·3	41·4	—	43·4

tives supplied by makers more or less to their own designs previous to Mr. Gooch taking over the responsibility of the locomotive department, undoubtedly the most successful were those built by Stephenson. In addition to the two already mentioned, this firm supplied ten other engines, two at least of which were converted from the 5ft. 6in. to the 7ft. gauge. An example of these locomotives is shown in Fig. 9; also one of several rebuilt subsequently as eight-wheeled tank engines—Fig. 10.

So far the locomotive stock had been of a heterogeneous and unsatisfactory nature, with but few exceptions; but in 1840 Mr. Gooch assumed the proper functions of a locomotive superintendent, and started a new era by the introduction of some small degree of standardisation. Fig. 11 shows one of a series of sixty-two tender engines built by various makers between the years 1840 and 1842, all practically to the same dimensions, though differing in details, and Fig. 12 illustrates a smaller type of twenty-one engines, also provided by different firms at about the same time. The example shown is remarkable, as it was the only one of the class fitted with Hawthorn's system of return tubes, a device which was ultimately removed. All these smaller engines were subsequently rebuilt as tank engines in the manner shown in Fig. 13.

The first goods engines built for the Great Western Railway were four-coupled, of the type shown in Fig. 14, and eighteen of these were supplied by various makers. They, however, in common with the preceding class, were afterwards rebuilt as tank engines. Fig. 15 illustrates one of the first four six-coupled engines built for the broad gauge, and it is additionally interesting as these were the only six-coupled engines built for the Great Western Railway 7ft. gauge with the frames outside the wheels. Shortly afterwards a six-coupled tank engine, not illustrated, was built for banking purposes, with the rather suggestive name of Avalanche.

Up to this date—1846 – Swindon works had not been capable of building complete engines, but Mr. Gooch now established the shops on a productive basis. The first locomotive built at Swindon was a six-coupled engine, one of a series of twelve, and it is illustrated in Fig. 16. Except for the haystack fire-box, this was practically the pioneer of the standard goods engines of the broad gauge, as will be seen by comparison with Figs. 16 and 23, which represent later examples. In fact, the building of engines at Swindon served to mark a dividing line between ancient and comparatively modern designs. The second engine built by the railway company was the famous 8ft. single Great Western, Fig. 17, which was thought to represent "the ultimatum of the broad gauge" at the time when the Battle of the Gauges was at its height, and Brunel's 7ft. track was striving to justify its existence. A comparison of Fig. 17 with, say, Fig. 11 shows the advance that had been made towards modern ideals of power. A mishap to the leading axle, which bore an undue proportion of the total weight, and was, moreover, defective, caused this engine to be rebuilt in the form shown in Fig. 18, and the accident therefore incidentally led the way to the introduction of what was afterwards the standard type of broad gauge express engine, which is illustrated by the first of the class in Fig. 19. A later engine of the same type is shown in Fig. 28. The eight-wheeled single engines of the G.W.R. broad gauge have been so frequently described that there is no occasion to give a detailed account of them in this place; but it may be mentioned that between the years 1847 and 1888 no less than 44 engines of this type, exclusive of the original Great Western, were built at Swindon and elsewhere, of which 23 were still in service at the time of the abolition of the broad gauge in May, 1892. The Iron Duke was one of the survivors, after a career extending over more than 47 years.

Immediately prior to the introduction of these relatively large engines, Mr. Gooch designed a type of six-wheeled express engines illustrated in Fig. 20, of which six were put in service. Following these came the first of the more modern series of goods engines, shown in Fig. 21. A comparison of this drawing with Fig. 23 shows slight differences in detail, the latter engine representing the type of goods engine that was standard for at least thirty years. In 1849 a new type of tank engine, intended to work through trains on the line west of Bristol in conjunction with the Bristol and Exeter and Devon and Cornwall Railways, was introduced, of which Fig. 22 shows the first. Two were built experimentally, and after an interval of several years, a further 13 of similar type, but differing slightly in dimensions, were brought out. Fig. 23, representing one of the standard goods engines, of which there were six "lots," comprising 141 engines altogether, built between the years 1846 and 1864, has already been referred to.

Though the well-known Iron Duke class of single-wheelers was, throughout the remaining period of the existence of the broad gauge, the standard type for express work, Mr. Gooch introduced several types of coupled engines, of

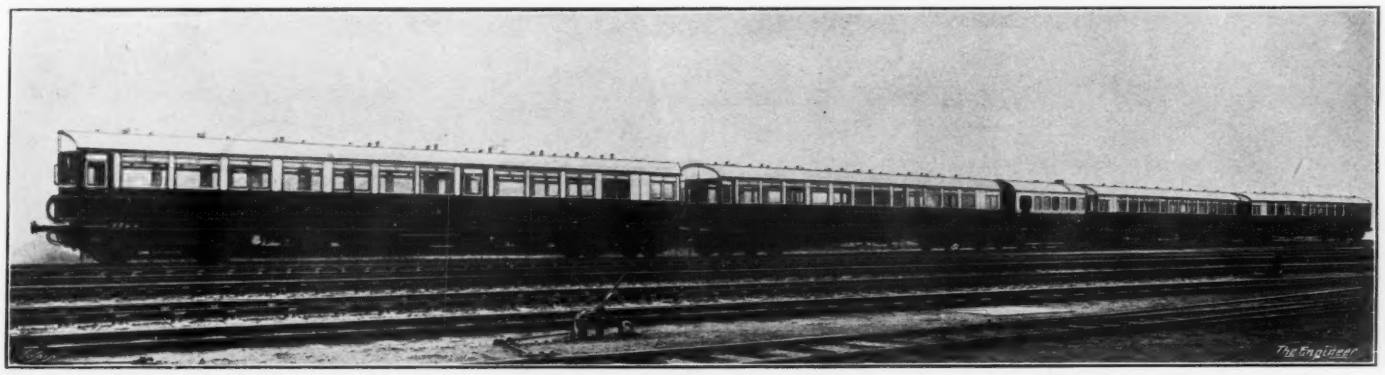


Fig. 35—PLYMOUTH MOTOR TRAIN

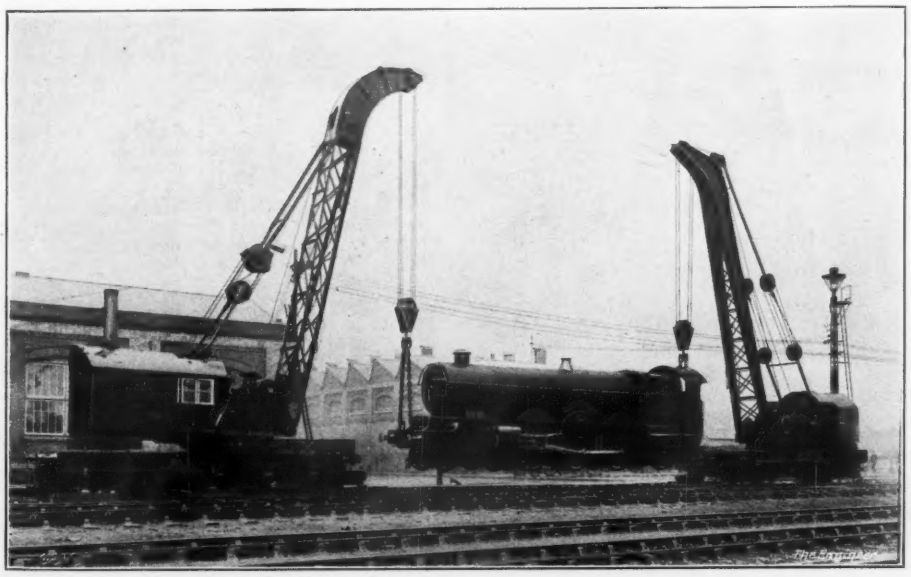
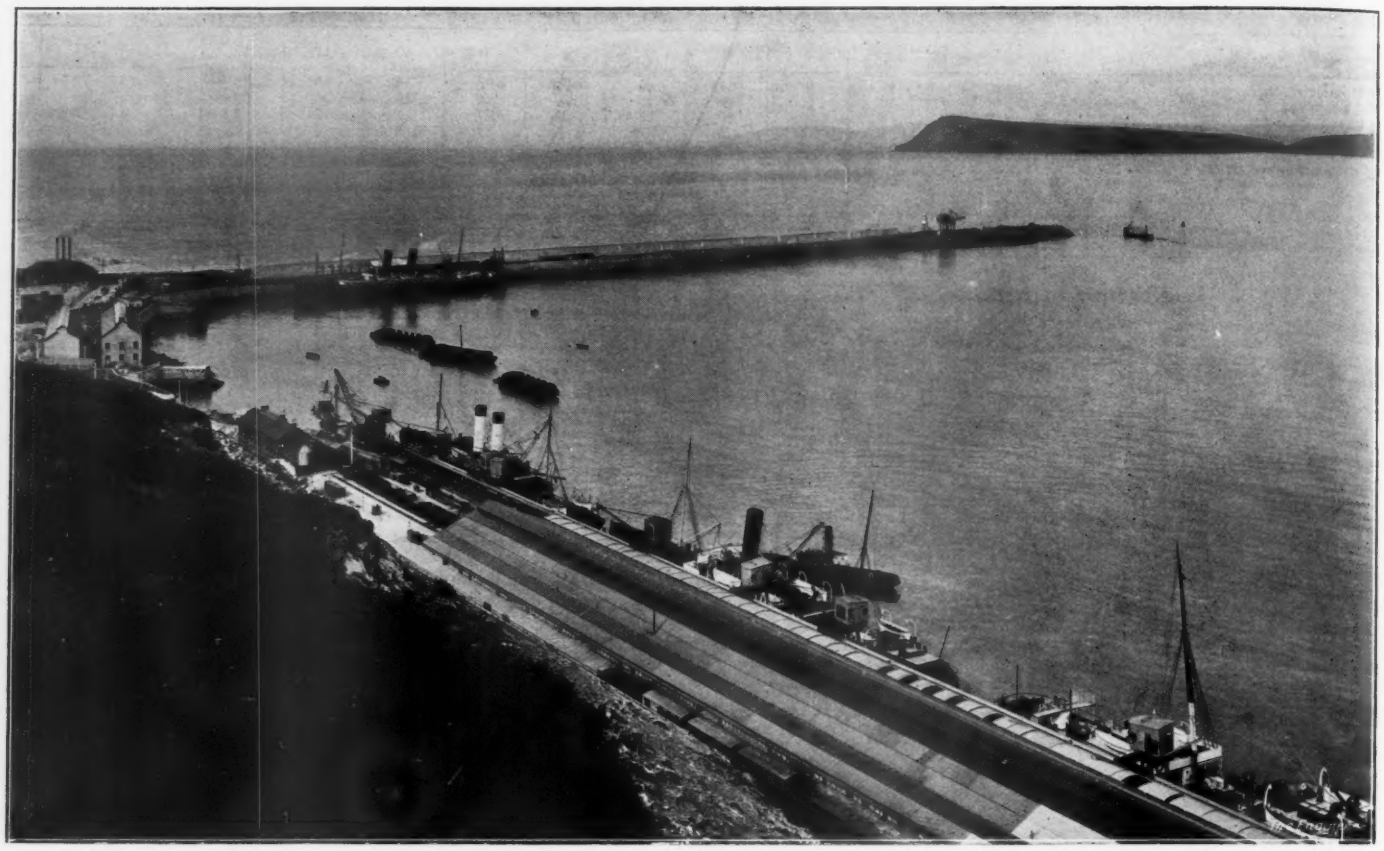


Fig. 36—STEAM CRANES LIFTING THE GREAT BEAR

GREAT WESTERN HARBOUR AT FISHGUARD



which two examples are illustrated. In Fig. 24 is shown the larger eight-wheeled class, of which ten were built in 1855; whilst Fig. 25 depicts one of 18 six-wheeled engines, built in two series in 1856 and 1863-4 respectively. At about the earlier of these dates a large number of the first engines placed on the line were rebuilt as tank engines, as has already been noted, there being a distinct need for increased engine power throughout the system. A further series of smaller four-coupled engines was built in 1865-6 to the number of twenty-six. These were of Mr. Gooch's design, but were completed after his retirement in September, 1864, by his successor, Mr. Joseph Armstrong.

A new phase in the locomotive history of the Great Western Railway was reached with the opening of the Metropolitan Railway on January 10th, 1863, that line being originally built to the requirements of the broad gauge, and worked for some months by Great Western Railway engines. For that purpose twenty-two tank engines were built to Mr. Gooch's designs—see The Engineer, August 16th, 1895 (Supplement), and September 6th, 1895, page 239 — which, after the Metropolitan Railway provided its own rolling stock, were converted into tender engines and worked local services on the Windsor and other branches.

Six six-coupled saddle-tank engines, built in 1866, and fifteen of the large 8ft. singles built in three series in 1878, 1880, and 1888, complete the tale of engines designed exclusively for the broad gauge. Fig. 28 shows one of the latest series of these eight-wheelers, which differed only slightly in dimensions and details from their prototype, Iron Duke. These fifteen were all built during Mr. William Dean's superintendence, Mr. Armstrong having died on June 5th, 1877.

Henceforth the final abolition of the broad gauge was held constantly in mind, and all further designs for locomotives were made subject to that threatened change. In 1883-4 Mr. Dean converted ten six-coupled narrow-gauge engines to the wider gauge by the simple expedient of fitting them with new axles, which brought the wheels outside the frame. One of these is illustrated in Fig. 26. The result was so successful that subsequently others of the same type were treated in a similar manner. Ten saddle-tank engines were also converted to broad gauge, and of twenty four-coupled side tank engines built in 1885, ten were built for the 7ft. gauge, with a view to subsequent reduction to the normal gauge when occasion demanded. These are shown in Fig. 27. They were afterwards rebuilt as tender engines. Another series of twenty side-tank engines, four coupled in front with a trailing bogie, were also built for the broad gauge, and were eventually converted to the narrow gauge.

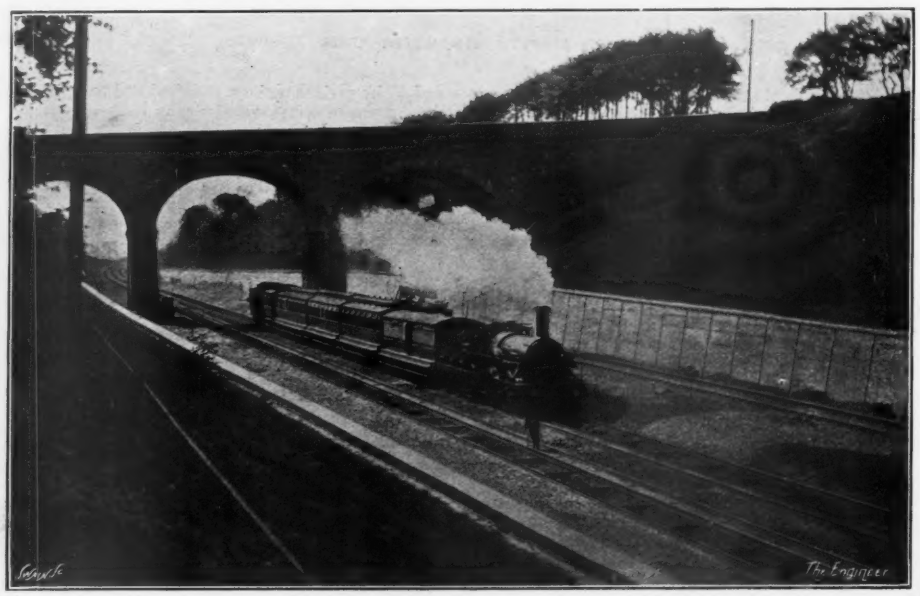


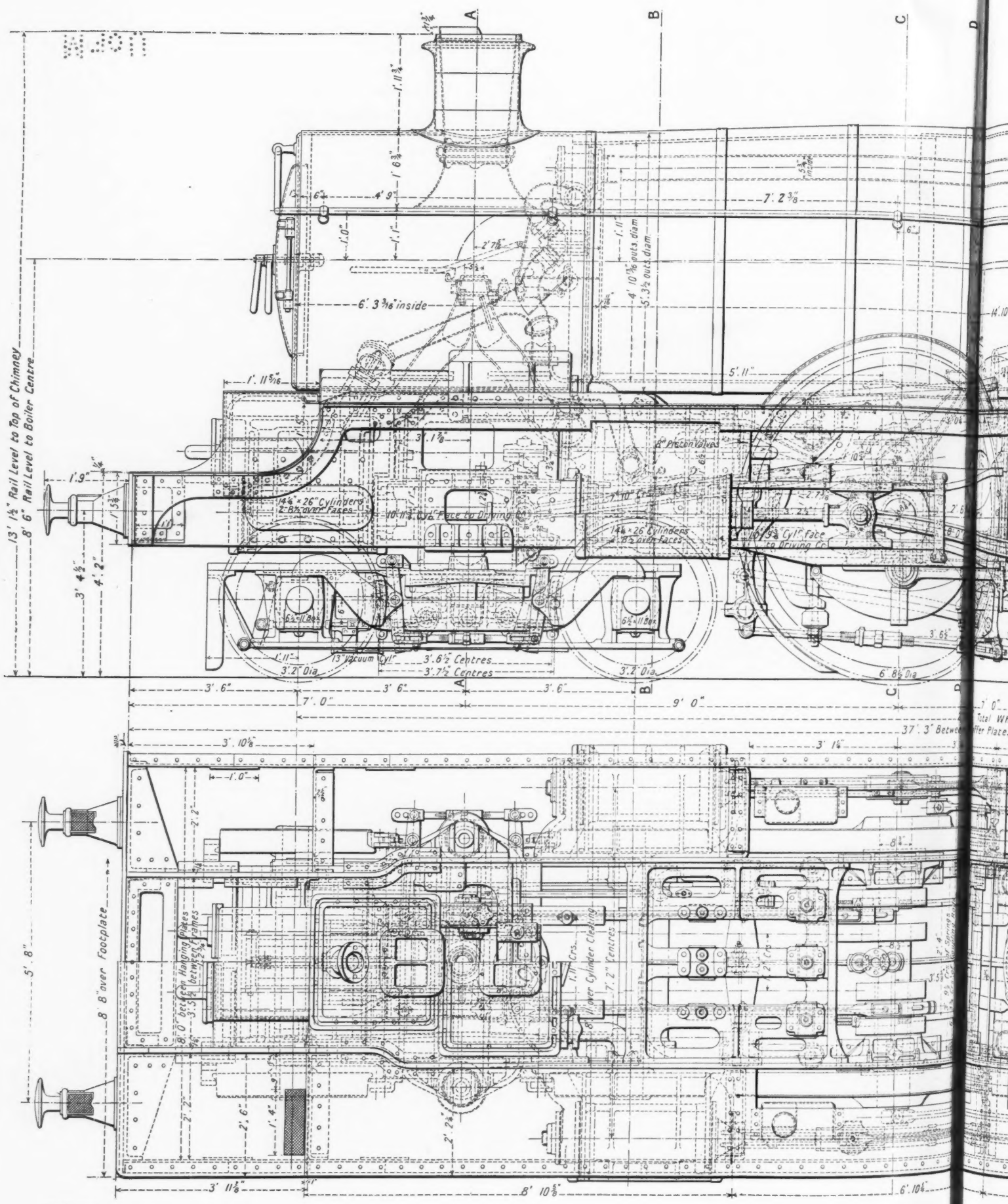
Fig. 37—LAST BROAD GAUGE TRAIN PASSING SONNING

The remaining series of engines built for the then immediately doomed broad gauge must be dealt with briefly. One was a six-wheeled four-cylinder compound, built in 1886, which, after exhaustive trials, was withdrawn from service and rebuilt for the narrow gauge as a four-coupled leading-bogie simple engine. Two four-coupled engines, of which one is shown in Fig. 29, were built in 1888, with a view to subsequent conversion. This, however, did not take place in the manner originally intended, for they made their appearance on the normal gauge in quite another form, similar to the compound previously referred to. Eight other engines, of the type shown in Fig. 30, were more successful. They worked broad-gauge trains with great regularity, turn and turn about, with the 8ft. engines, for about a year prior to the withdrawal of the wide stock, and then were converted to the narrow gauge, with little alteration except as regards axles and axle-boxes—see The Engineer, October 21st and 28th, 1892. Subsequently, however, they developed the same fault as the original Great Western, in respect to undue weight at the leading end, and their front wheels were removed and a bogie substituted. In this form they comprised a portion of the fine series of 80 bogie single-driver locomotives—see The Engineer, Nov. 2nd, 1894—which for some years hauled the most important trains of the Great Western express service—until, in fact, the introduction of dining cars and heavy corridor stock rendered the use of coupled wheels imperative.

With these engines we conclude a necessarily brief sketch of the locomotive history of the Great Western broad gauge, a subject to which justice could be rendered only by a special issue of The Engineer devoted entirely to that matter. During the process of absorption of other broad gauge lines, such as the Bristol and Exeter and Devon and Cornwall railways, and others, many engines of an interesting character were taken over by the Great Western Railway and incorporated in its stock, but to attempt any account of these, however brief, would swell unduly this review.

FOUR-CYLINDER SIX-COUPLED PASSENGER L

MR. G. J. CHURCHWARD, M. ... C.E.



"The Engineer"

E LOCOMOTIVE, GREAT WESTERN RAILWAY

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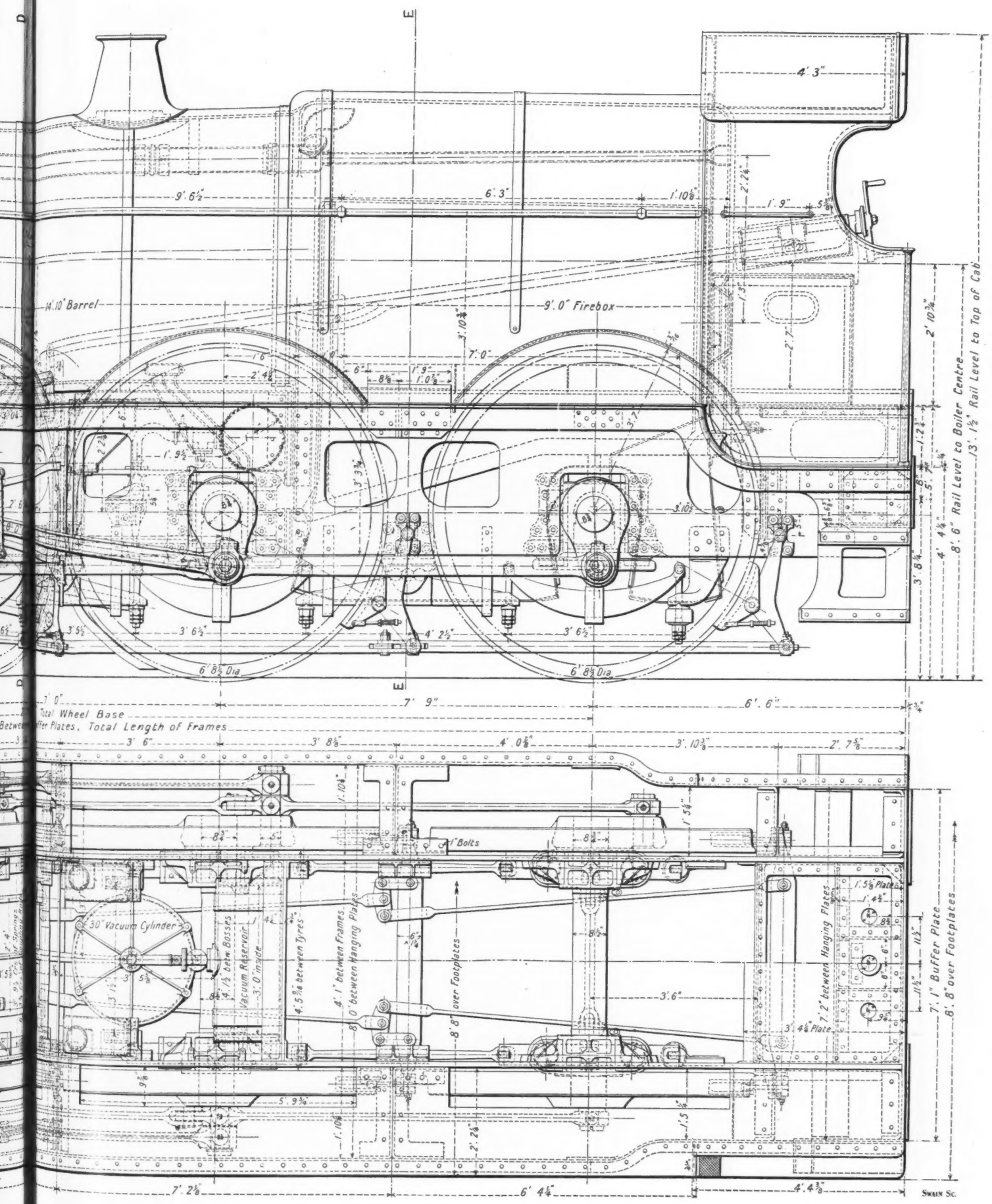

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"THE ENGINEER"

PASSENGER AND GOODS LOCOMOTIVES

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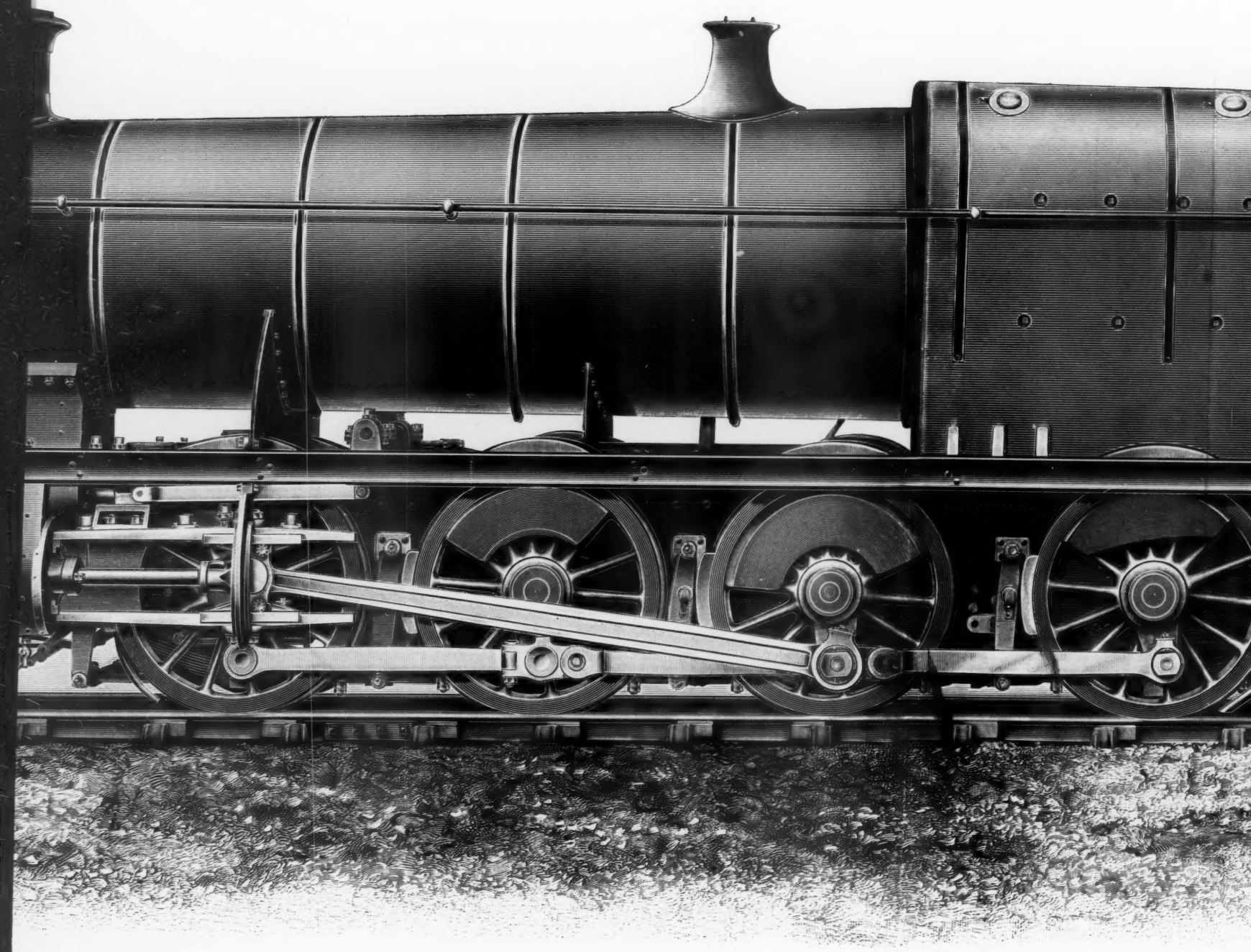

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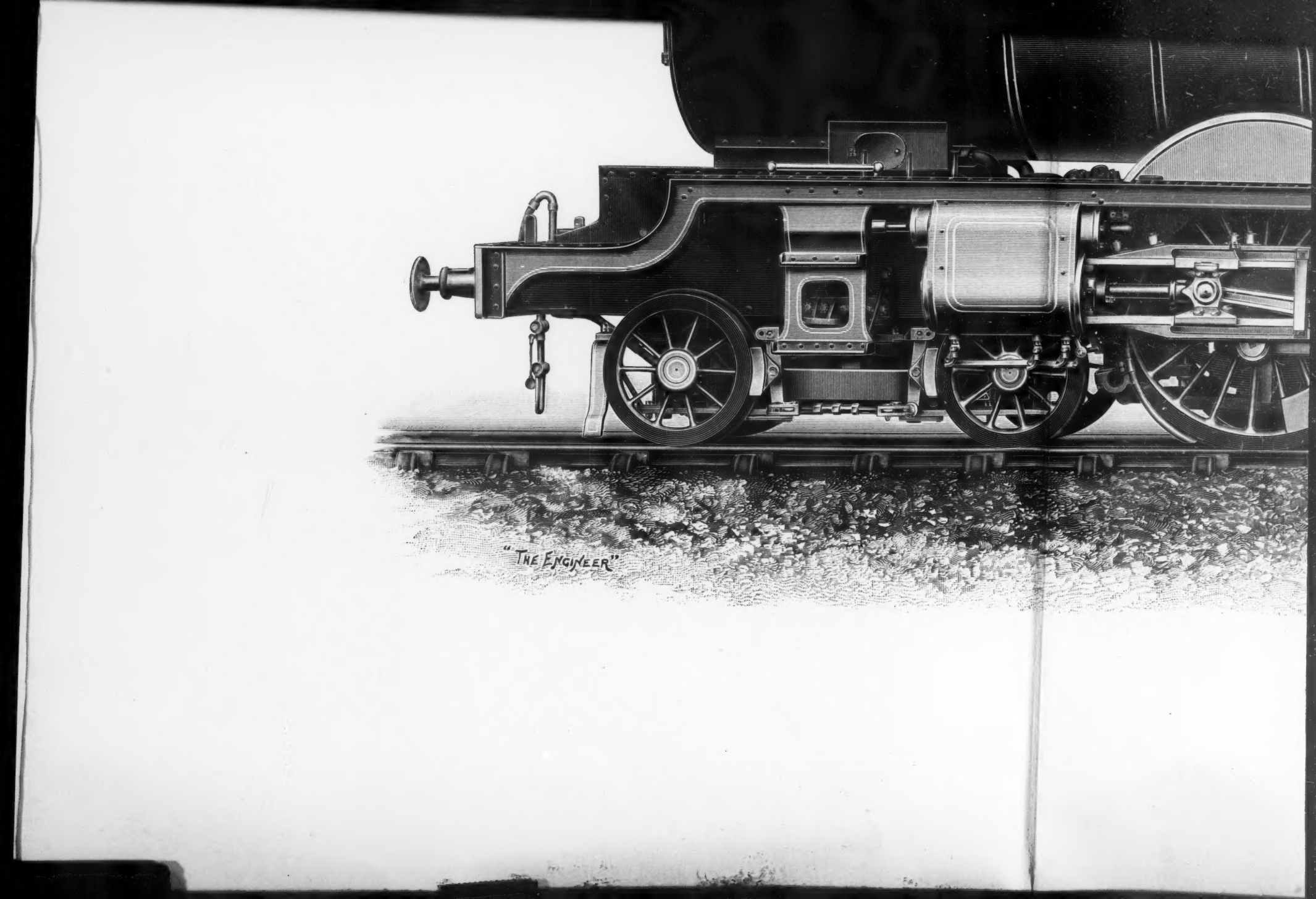
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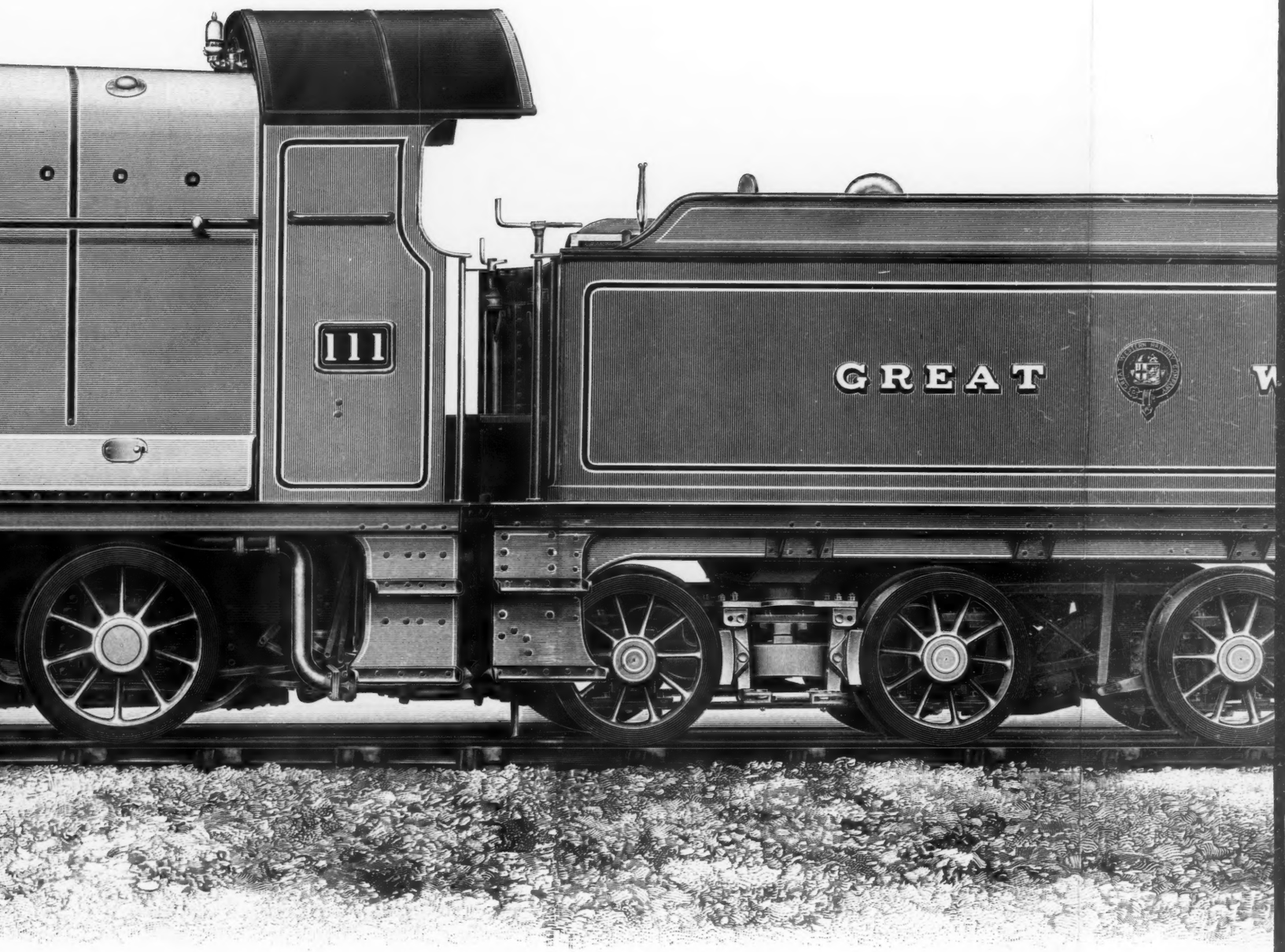
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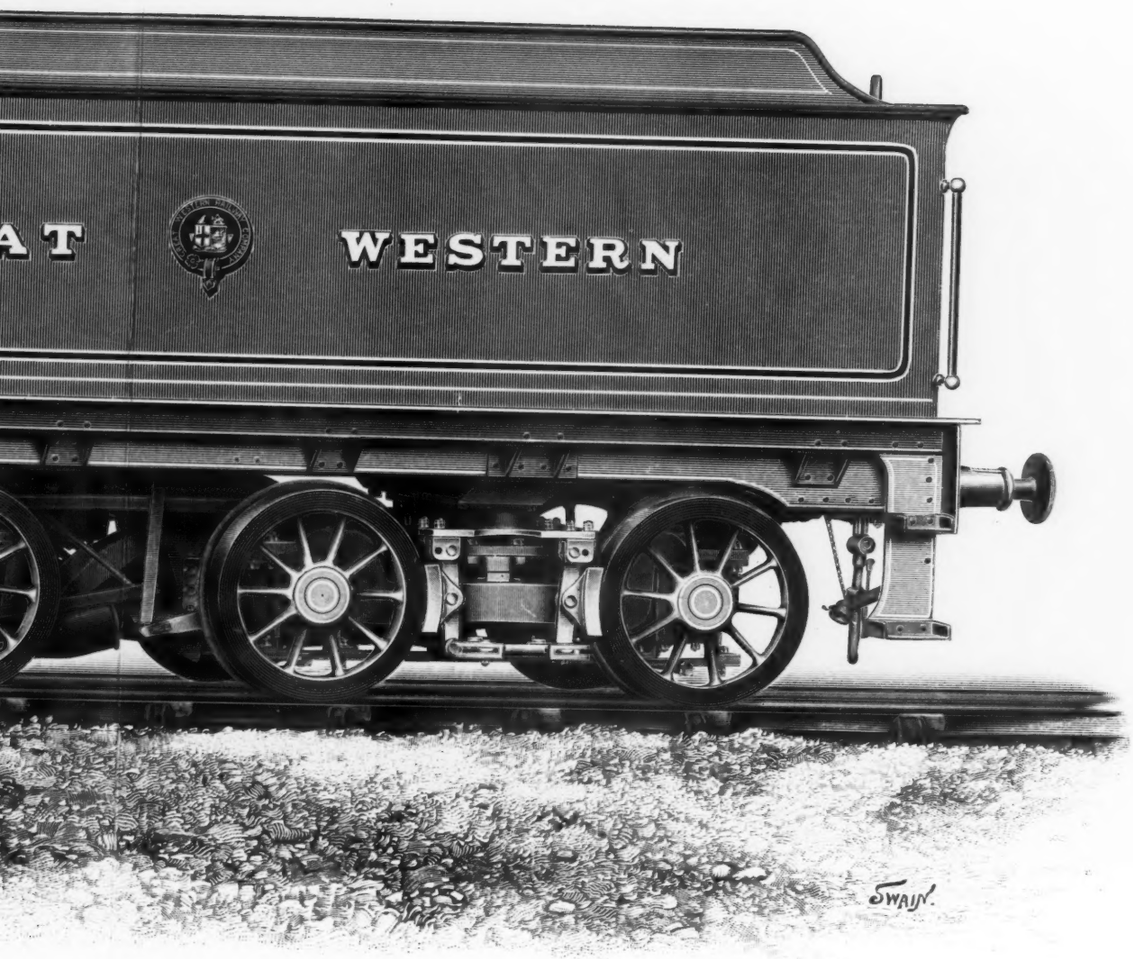
AT
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THE PROGRESS OF ENGINEERING IN SOUTH AND CENTRAL AMERICA.

(By our Special Commissioner in South America.)

No. XXV.*

La Paz, Bolivia, June 16th, 1910.

In THE ENGINEER of the month of April last year there appeared an article from my pen dealing with the proposed construction of the Arica La Paz Railway, and there it was mentioned that active work would commence in the following month of August. The undertaking possessed a peculiar interest for your readers in view of the fact that, after very severe competition on the part of Germans and Americans, for the contract to build this railway, it was finally secured by the firm of Sir John Jackson, and a small company composed of Sir John Jackson and Mr. Norton Griffiths was formed under the title of Sir John Jackson (Chile), Limited, for the purpose of dealing with the undertaking.

The work, briefly, involves the construction of a metre gauge line from the Pacific coast of Chile, at Arica, which was formerly Peruvian property, across the main range of the Andes to La Paz, the capital of Bolivia, and is an enterprise which is fraught with far reaching consequences, both political and commercial. The line will have a total length of 440 kiloms., or 260 miles, and it will be of the one gauge throughout, the same as has been adopted by the two existing trans-continental lines, namely, the Antofogasta and Bolivia Railway, which runs from the Port of Antofogasta to La Paz, and the Southern Railway of Peru, which runs from the Port of Mollendo, across the Lake of Titicaca, also to La Paz.

Starting from Arica, the line runs up the Lluta valley for a length of 40 kiloms., where the maximum grade is 2 per cent.; it then commences to climb, and between kilom. 40 and kilom. 70 the grade attained is 3 per cent. Between kilom. 70 and kilom. 105 is not only found the steepest but the most difficult part of the line, and here a 6 per cent. rack grade is adopted. At kilom. 190 the highest point of the line is reached, namely, 14,000ft. above sea-level, and between kilom. 105 to the frontier, at Charana, the maximum grade is 3 per cent., while from Charana to the terminus at Alto-de-la-Paz the maximum grade is again 2 per cent.

The most difficult portion of the line on the Chilian section, namely, between kilom. 70 and kilom. 105, has already been tackled, and some exceptionally heavy work is now proceeding. Here it will be necessary to construct six short tunnels and some very deep rock cuts and fills, in addition to a number of heavy masonry retaining walls. With regard to the said tunnels, the longest will be 250 m. and the shortest 120 m. Two of these have already been completed, and the remainder on the Chilian side will be got through, in addition to all other earthworks, by December next. On the Bolivian side, all earthworks will likewise be completed by the end of this year. In this section the heaviest portion of the work is found in the Mauri Gorge, at kiloms. 232 to 272, and consists principally of side-cutting work in solid rock and the removal of some immense boulders of stone. At one time it was believed, and, in fact, emphatically stated, that the engineering difficulties of this section were so great as to render the work impossible of completion. Several experienced engineers were of this opinion, but Mr. Mateo Clark, whose experience of South American railway construction is probably only second to that of the famous Meiggs Brothers, and who, accompanied by a Government engineer, surveyed the present road some years ago, always considered the scheme a practical one, and as presenting no difficulties which could not be overcome. Mr. Clark's judgment has proved correct, and it is satisfactory to know that the constructing engineers have proceeded so far with the work as to be able to state without hesitation that it will not only be completed, but far within the stipulated period, which, by the terms of the Government contract, they are allowed.

With regard to the bridges, these have also proved far fewer in number, and less costly than was at one time considered probable. Upon the Chilian section there will be no bridges of any importance, since the line runs through a practically dry country, where only culverts are called for. On the Bolivian side, however, there will be several important bridges, the principal one being that over the Mauri River, which will consist of twelve spans of 10 m., deck-girder type, and which is now being constructed by a British firm of engineers; another is that over the Rio Colorado, also consisting of ten spans of 10 m. each; a third, that over the Desaguadera River, a stream which joins Lake Titicaca with Lake Popolo, and which will consist of eight spans of 10 m., deck girder-type; a fourth, that over the Rio Pontesuelo, consisting of four spans of 10 m., and a considerable number of single-span openings ranging between 10 m., 5 m., and 3 m., as well as several arched culverts and pipes. Some of the finest stone which it is possible to obtain, and which closely resembles the finest granite, is being used for the abutments of the bridges, and the whole of the construction work, so far as it has gone, reflects the very highest credit upon the contractors.

Under the contract the main curvature of the line is to be 100 m., while the steepest gradient is the 6 per cent. rack section on the Chilian side, above referred to. The weight of rails employed is 60 lb. per yard for a length of 100 kiloms. on the Bolivian section, laid upon American redwood sleepers; and the balance of the track, namely, 340 kiloms., will have 55 lb. rails laid upon Chilian oak and American redwood sleepers.

In the whole length of the 440 kiloms. of line, there will be between eleven and twelve stations, namely, the terminal at Arica, and five stations on the Chilian side, and the La Paz terminus and six or seven other stations on the Bolivian side. With regard to the precise Bolivian terminus, it is necessary to point out that some uncertainty still exists owing to the fact that efforts are being made to modify the original contract so as to stop the Bolivian section of the line at Viacha. These efforts, I should add, do not emanate from the contractors of the Arica-La Paz Railway, but from the Antofogasta and Bolivia Railway Company, which will be the most seriously affected should the line be brought from Viacha into La Paz.

It has long been the intention of the Antofogasta and Bolivia Railway, whose line at present stops at Viacha, and whose trains from Antofogasta to La Paz can only enter the latter city over the line of the Guaqui and La Paz Railway—leased to and managed by the Peruvian Corporation—to construct its own line from Viacha into La Paz. The matter referred to is now under the consideration of the two Governments of Bolivia and Chile, whose mutual consent must be obtained before any diversion from the original contract can be permitted. Even after that consent is obtained, if, indeed, it is, an arrangement will have to be made with the contractors of the Arica La Paz Railway, who will justly expect and demand substantial compensation for the abandonment of this section of the line—Viacha to La Paz—more especially as being the easiest part of the construction, it means to them the largest amount of profit upon the contract.

The actual amount of work accomplished up to date—June 16th—embraces the laying of rails to kilom. 80 on the Chilian side and to kilom. 100 on the Bolivian side. By the end of the present year the contractors hope to have rails on the Bolivian side laid to kilom. 180 and on the Chilian side to kilom. 100, which will thus leave only 260 kiloms. to complete, and this, it is confidently expected, will be successfully accomplished by the month of July or August, 1911. The first train will probably be run through shortly after that date, and it is well to bear in mind that, by the terms of the contract, the line need not be finished until the month of April, 1912.

It will be readily observed how rapid has been the work carried out, the contractors only having commenced active operations in the month of August, 1909. They have been fortunate with regard to the labour secured, both as to quantity and quality. Normally, some 3000 men are employed on the whole of the two sections, but, just at present, the number engaged does not much exceed 1500, due to the fact that most of the men are away harvesting. By the time these lines appear in print, however, the contractors expect to be employing nearly 4000 men on the two sections, and the full complement of labour will continue until the coming spring, when the usual cessations will take place in connection with the planting season. The rate of pay for the Indian peons is 1.50 dols. (2s. 3d.) per day, the contractors providing habitations but no rations. They run their own provision stores, and they find that the enterprise works out about even. The overseers, who are mostly Europeans, with one or two Americans, receive from 200 dols. to 300 dols. (£15 to £25) per month. In practically all cases the masons employed are either Austrians or Italians, and it is satisfactory to say that, so far, no serious trouble with any of the workpeople has been encountered.

A very important problem which will have to be faced when the railway is completed and in running order is the employment of Europeans upon the regular working staff. It will be remembered that the highest altitude attained on the Arica-La Paz line is 14,000ft., and this great height has a serious effect upon a large amount of the labour engaged. Europeans, as a general rule, cannot stand such an altitude, and in all probability would not be able to do at it one-half of the work of which they would be capable on the coast. It has been found by experience that the output per man, even at altitudes of but 6000ft. or 9000ft., has been reduced by fully 20 per cent. It is too early to be able to say what system of employment will be adopted, but it is supposed that the European portion of the staff will be brought up as far as it can stand the altitude, while, beyond, Indians will be employed. A large proportion of foreigners who come to these high altitudes never completely overcome the disease of "siroche" or mountain sickness, and some few are so seriously affected that they are compelled to return to the lower levels almost at once. Nor is "siroche" the only physical obstacle encountered, for a violent extreme of temperature is met with, as may well be believed when it is said that at one point on the road, namely, the headquarters at Mauri River, there is frequently shown a divergence in the temperature of between 27 deg. below zero Centigrade (equals 50 deg. Fah. below freezing) and 24 deg. above zero, or a difference of nearly 100 deg. Fah. in twenty-four hours.

Reference has been made to the excellent character of the work which has been put into the construction of the Arica-La Paz Railway, but something more may be said as to the thoroughness with which the work was entered upon from the very beginning. One of the first undertakings was to re-survey the entire line from end to end, since it was found, upon preliminary examination, that the Governmental surveys were anything but satisfactory, and that, with care, they could be considerably improved upon. This supposition was abundantly justified, since the result of the new survey has been to shorten the line by 12 kiloms. and to reduce the quantities by 1,500,000 cubic metres. At the same time, the main line will have been much improved from a running point of view. The final part of the survey is still proceeding, but it will be completed in its entirety within three or four weeks from this date.

As an instance of the arduous work involved in the new survey, it may be mentioned that on the Chilian section between kiloms. 70 and 110, the work had to be gone over six or seven times, since this section has proved the most difficult in the experience of all the engineers in which to locate a line, a divergence of even 2ft. making a considerable difference. I learn from the engineers in charge that they are now completely satisfied that they have as perfect a survey as could possibly be obtained, and one which will mean not only a far better working track, but will secure a decided economy in construction. Work has proceeded sufficiently far to enable the engineers to calculate exactly what the future cost of construction will be, and they have also been enabled to get out all the quantities up to the last portion of construction. It may be said with perfect confidence that nothing can now interfere with the successful completion of the undertaking barring an earthquake or some such similar catastrophe. Even this contingency, however, is remote, although Arica has by no means been inexperienced in seismic troubles.

There can be no question that the completion of the Arica-La Paz Railway will make a very considerable difference to the future prosperity of both the Antofogasta and Bolivia Railway and the Southern Railway of Peru, but far more with regard to the latter than to the former. It is over the lines of the Southern Railway that the bulk of traffic finds its way to La Paz, but with the completion of the new line the distance of haulage from the coast will be shortened by some 700 kiloms., in addition to which the port of Arica is a better harbour than either Antofogasta—Antofogasta and Bolivia Railway—or Molendo—Southern Railway. By means of the newly constructed railway it will be possible to travel from La Paz to Arica in sixteen hours, as against thirty-nine hours by "express," and nearly three days by ordinary train between La Paz and Mollendo, upon the tracks of the Southern line; the time occupied between La Paz and Antofogasta is two days. It is intended to introduce a schedule upon the Arica-La Paz Railway, by which passengers can leave the capital of Bolivia at 5 p.m. on one day and arrive at the port of Arica at 9 a.m. the following morning, the train being made up of sleeping and dining-cars as well as ordinary first-class and second-class coaches.

The construction work upon this new and important line of railway has been divided into two sections, namely, the Chilian and the Bolivian, the former being under the superintendence of Mr. Norton Griffiths, who has already shown himself an exceedingly capable and competent organiser. It was Mr. Griffiths who built the Benguella Railway, which connects the copper mines in Kapanga, Southern Congo, with Lobito Bay, Portuguese West Africa. Mr. Griffiths has as assistant, Mr. Wynne Edwards, also an able and experienced engineer. The Bolivian section is under the superintendence of Mr. James McLean Alexander, an engineer of great capability, who has seen considerable experience as a railway constructor in the southern portion of Chile.

* No. XXIV. appeared December 9th.

JET v. SURFACE CONDENSERS.

By R. M. NEILSON.

MUCH has already been written in the way of describing different kinds of condenser, and pointing out their merits; and much advice has been given as to what type of condenser it is best to employ under certain conditions as regards quality and quantity of condensing water.

Such general advice as is usually given as to type—where such advice is unbiassed—applies, however, chiefly to cases where the practical engineer requires no advice owing to the proper choice being obvious or easily ascertained.

There is, however, a constantly increasing number of cases in connection with condensing plant for either high or low-pressure steam turbines, where it is not obvious which is the best type of condenser to employ, and where, in fact, the wrong condenser is not infrequently selected.

Comparatively little appears to have been written which is applicable to such cases, and which is of use to the power user in coming to a decision as to what type of condenser to adopt.*

The present article will deal with two types of condenser only—the surface condenser and the barometric jet condenser—with a view to showing the field in which each type may profitably be employed in conjunction with steam turbines employing either high pressure or low-pressure steam.

Before considering the difficult cases, which it is the chief object of this article to deal with, it may be advisable in the first place to briefly refer to the cases where there can be little doubt as to which condensing system it is better to adopt, even although nothing new will be said on this part of the subject.

If plenty of condensing water is available, but the water is not suitable for boiler feed, it is advisable to employ surface condensers. For example, surface condensers are, with a very few exceptions, always employed at sea; and, in certain cases, river or canal water may be good enough for use in condensers but not good enough for boiler feed purposes. At the McDonald-road Electric Power Station in Edinburgh, water from the city sewers is employed for condensing purposes in surface condensers.

In some cases the water may be not only too bad for use in boilers, but also too bad for use in surface condensers, although usable in jet condensers; but a limited quantity of good water may be available, in which cases jet condensers may be used and the feed drawn from the supply of good water.

The more difficult cases will now be considered, and these can be divided into two classes. First, there is the case where plenty of water is available which can be employed in a surface condenser, and can also be employed in a boiler. Secondly, there is the case where little water is available, or the price is high, the water being, as before, suitable for use both in surface condensers and in boilers. In both cases either jet or surface condensing systems may be employed, but, in the latter case, a cooling tower, or some equivalent water-cooling arangement, must be provided.

Jet condensing plant involving the employment of a barometric water discharge pipe costs less than surface condensing plant to maintain the same vacuum under the same conditions; but more power is required to drive the

* Some valuable data are, however, given in a paper read on November 13th, 1909, by Mr. W. A. Dexter, before the Glasgow Technical College Scientific Society, and entitled "Notes on Steam Condensing Plant and Exhaust Steam Installations."

air pump in the jet condensing system than in the other on account of the air admitted to the condenser with the condensing water.

Water at ordinary temperatures can retain in solution from 2 to 3 per cent. by volume of air. The gas, or mixture of gases, found in condensing water usually differs more or less in composition from atmospheric air, although it is commonly, and without much harm, spoken of as air; it will be called air in the present article.

Water in motion in contact with the atmosphere often contains over 3 per cent. of "air" by volume, and sometimes over 4 per cent. The water, in many cases, is supersaturated, and will give up some of the air if allowed to stand, even without any increase in temperature or reduction in pressure.

Lower pressures are usually required to be maintained in condensers for turbines than in condensers for piston engines, and therefore a greater ratio of condensing water to steam is required in the former than in the latter for the same admission temperature of the circulating water The question of air admitted to a jet condenser with the condensing water is therefore usually of more consequence with turbines than with piston engines.

Moreover, with turbines, if sufficient care is taken, little air should be admitted to the condenser with the steam, and this constitutes all the air which gains access to a surface condenser, while a jet condenser gets the air with the steam, and also the air with the water.* Therefore, comparing the work to be done by the air pump of a jet condensing system with the work to be done by the air pump of a surface condensing system, the ratio of the one to the other is usually much greater in the case of steam turbines than in the case of piston engines.

Another important point to bear in mind in connection with condensing plant for steam turbines is that a difference in pressure between the condenser and the exhaust end of the turbine is most important. There is necessarily a certain difference in pressure between the steam at these points in order that a flow of steam may take place, but it is worth while going to some trouble and expense to prevent this difference in pressure reaching a high value. This fact will be appreciated when it is mentioned that to lower the condenser pressure from 1.5 lb. to 1.25 lb. per square inch (*i.e.*, to increase the vacuum about half an inch) will, in the case of surface condensing plant for a 3000-kilowatt turbine, involve an increase in total cost of condensing plant, including a natural draught cooling tower of from £300 to £500.

It is usually possible to place a surface condenser directly below the turbine which exhausts into it, so that a short and direct exhaust steam pipe is obtained; and the difference in pressure between turbine and condenser is almost negligible. On the other hand, the long exhaust pipe which it is usually necessary to employ with a barometric jet condenser, and the necessity of drawing the wet steam upwards through this pipe, together with the fact that the pipe usually contains two bends and that water may collect in the lower part of it, are conducive to a considerable drop in pressure between the turbine and the condenser. This drop in pressures varies with different plants, and even with the same plant, at different times or under different conditions, and may be anything up to a quarter of a pound per square inch. It is, therefore, usually necessary to design a barometric jet condensing plant for a higher vacuum than would be necessary with surface condensing plant to maintain the same terminal pressure at the turbine.

As with a barometric jet condenser, the vacuum in the latter can be employed to draw the condensing water into the condenser, or at least to assist in this action, and as the water is discharged by gravity, while with a surface condenser a certain frictional head has to be overcome, there is a saving in water pumping power to the credit of the jet condenser in this respect. On the other hand, when a cooling tower is employed in conjunction with a barometric jet condenser, it is usually expedient to employ two condensing water pumps—one to deliver the water to the condenser and the other to deliver it to the cooling tower—whereas in the case of surface condensing plant a single pump can force the water through the condenser and up to the distributing troughs in the cooling tower.

It has often been said that δ* can be lower with a counter-current jet condenser than with a surface condenser owing to the condensing water in the former coming into actual contact with the steam, while in the latter the two fluids are separated by the metal of the condenser tubes, and it has been argued from this that less condensing water is required in a jet than in a surface condenser. It is true that in a counter-current jet condenser δ may have a value close to zero, but this may also be obtained in a surface condenser by suitable design. Unless, however, the external head is high—as, for example, when a cooling tower is employed—or unless the quantity of water employed is of great moment, it is not usually desirable to strive to obtain a low value of δ with a surface condenser, as the benefits to be derived from this do not pay for the extra cost of obtaining it. With cooling towers, however, it usually pays to design the condenser to give a low value of δ.*

Another statement often made which requires qualification is to the effect that a higher vacuum can be obtained with a surface than with a jet condenser. In every case as high a vacuum could be obtained with a jet condenser as it would pay to obtain with a surface condenser; but the cost of obtaining the vacuum with the jet condenser might be prohibitive. That is, a vacuum which it may pay to obtain with a surface condenser may be beyond the economic limit with a jet condenser.

As already mentioned, barometric jet condensing plant costs less than surface condensing plant, but requires more power. In order to ascertain which plant it is best to employ in any non-obvious case, it is necessary to compare the capital outlay costs with the running costs. The former has a relatively greater importance compared with the latter if the plant has a low-load factor, whereas with a high-load factor the latter is of relatively great moment compared with the former. In the present investigation condensing plant for a 3000-kilowatt turbine has been considered, and the fixed annual costs, which are proportional to the capital outlay, and are independent of the load factor, are taken at 15 per cent. of the capital outlay in the case of surface condensing plant, including a cooling tower, and 13½ per cent. in the case of barometric jet condensing plant, including a cooling tower. Where a cooling tower is not employed, 13 per cent. has been taken in the case of the surface plant, and 11 per cent. in the case of the jet plant.

The annual running costs, which are proportional to the load factor or to the number of hours that the plant is worked in a year, differ chiefly as regards the work absorbed in driving the air pump; and this work, with its incidental expenses, has been taken at 0.6 penny per effective horse-power hour delivered to the air pump piston-rod or crank shaft.

Considering, in the first place, a case where a cooling tower is employed, and a turbine terminal pressure of 2 lb. per square inch is desired, the cost of surface condensing plant is estimated at £3860, which cost includes a natural draught cooling tower capable of reducing the temperature of the condensing water to 82 deg. Fah. Barometric jet condensing plant, capable of maintaining the same terminal pressure, is estimated to cost £3710. In arriving at the latter figure the pressure in the jet condenser has been assumed to be 0.13 lb. per square inch less than at the exhaust end of the turbine to allow for drop in pressure in the long exhaust pipe and difference in level between condenser and turbine; 15 per cent. of £3860 is £579, which represents the fixed annual cost on the surface condensing plant; 13½ per cent. of £3710 is £500, which represents the fixed annual cost on the jet plant.

The ordinates in the figures represent annual cost, distances below the zero line being in favour of the jet condenser and distances above the line in favour of the

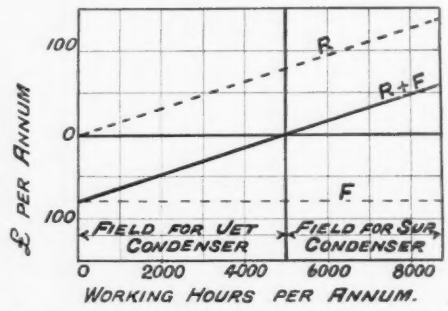


Fig. 1—Inlet temp. of circ. water 82 deg. Fah. Terminal pressure at turbine 2 lb. per square inch abs.

surface condenser. The actual costs are not indicated on the diagrams, but only the differences between the costs of the rival plants. In Fig. 1 the line F represents the difference in the fixed annual costs between the surface and jet plants for the case just mentioned, that is, the difference between £579 and £500, which is £79. This is in favour of the jet plant, and is independent of the number of hours during which the plant is worked in the year.

As regards running costs the air pump of the jet condensing plant is estimated to require 14.13 horse-power, and, therefore, at 0.6d. per horse-power hour to cost 8.5d. per hour at full load; and the corresponding figures for the surface condensing plant are reckoned to be 7.76 horse-power and 4.7d. per hour; the difference in cost in favour of the surface plant is, therefore, 3.8d. per hour at full load. The cost of driving the water pumps may be assumed to be the same in both cases. Curve R in Fig. 1 represents the difference in running costs for any number of working hours per year from nothing up to 8760, which latter figure represents continuous working. The greater the number of working hours per year, the greater, of course, is the advantage which the surface plant possesses over the jet plant. The heavy line marked R + F is obtained by taking the algebraic sum of the ordinates of the lines R and F; and this line represents the net difference in annual cost of the two systems for any number of working hours per year. It will be seen that the jet condenser has the advantage up to 4989 hours per annum, and thereafter the surface condenser has the advantage. Where the working hours are less than about 5000 per year at full load, it is therefore advantageous to employ a jet condenser, but, where the full power is carried for more than 5000 hours per year, it is better to employ a surface condenser.

As regards working at fractional load, the power consumed by the condenser auxiliaries then constitutes a greater percentage of the power of the main unit than is the case at full load. For the purposes of the present investigation, the motors driving the condensing plant are assumed to be designed to take for short periods a load considerably greater than the rated full load. A certain number of hours at a load which is a small percentage below full load may be taken as balancing an equal number of hours at which the load is about the same percentage above full load. Moreover, one hour at half load may be taken as equivalent to three-quarters of an hour at full load, so that, for example, if the plant were always running at half load, the costs for jet and surface plants, instead of being the same at 4989 hours, would be the same at 6652 hours per annum.

Fig. 1 shows that, under the conditions assumed, namely, a terminal pressure at the turbine of 2 lb. per square inch, and the employment of a cooling tower, there are fields of considerable extent both for the barometric jet and for the surface condenser.

For terminal pressures greater than 2 lb. per square inch, the field for the jet condenser is enlarged, and that for the surface condenser is reduced; but terminal pressures much above 2 lb. are seldom desirable for steam turbines.

For terminal pressures much lower than 2 lb. per square inch, the jet condenser has a very limited field. Fig. 2 corresponds to Fig. 1, but with plant designed for a terminal pressure of 1.5 lb. per square inch, a cooling tower being employed as before. The cost of the surface condensing plant is, in this case, estimated to amount to £4320, and the jet plant is reckoned to cost £4150. Fifteen per cent. on the former sum amounts to £648, and 13½ per cent. on £4150 amounts to £560; the difference in the fixed annual costs is, therefore, in this case £88,

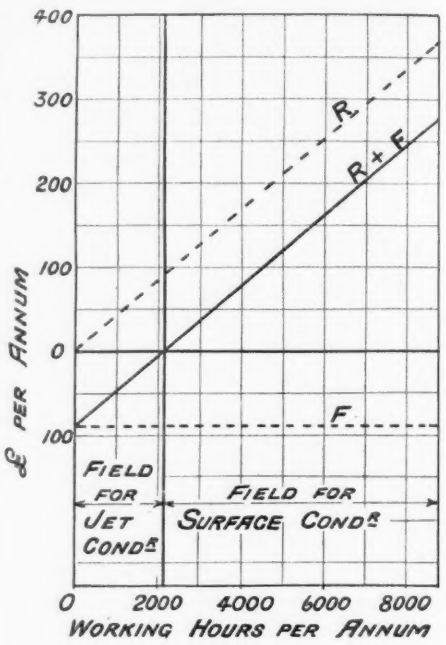


Fig. 2—Inlet temp. of circ. water 82 deg. F. Terminal pressure at turbine 1.5 lb. per square inch abs.

and this is represented by the line F in Fig. 2. The working costs are higher in this case than in the last case, especially as regards the jet plant, which suffers not only from the greater specific volume of the air due to the lower pressure, but also from the greater weight of air admitted to the condenser due to the greater amount of condensing water required. The air pump of the jet plant is in this case estimated to require 26.8 horse-power, and, therefore, to cost 16.1d. per hour at full load, while the surface condenser air pump is reckoned to require 10.09 horse-power, and therefore to cost 6.1d. per hour at full load, the difference in running costs being therefore 10d. per hour. The line R in Fig. 2 shows the difference in the running costs per annum for any number of working hours per annum; and the heavy line marked R + F represents the difference in total annual cost. It will be seen that the jet plant has the advantage only if the plant is worked per annum an amount equivalent to less than 2112 hours at full load.

Cases will now be considered where no cooling tower is employed, and where condensing water can be obtained

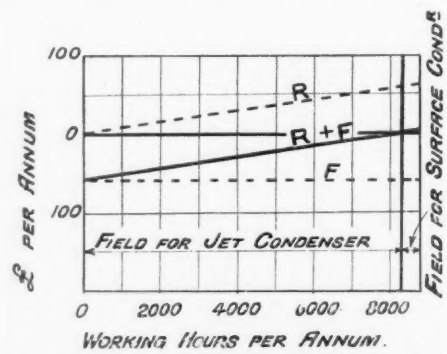


Fig. 3—Inlet temp. of circ. water 60 deg. F. Terminal pressure at turbine 1.5 lb. per square inch abs.

at a temperature of 60 deg. Fah. The lesser amount of condensing water required in such cases enlarges the field for the jet condenser, so that for a terminal pressure of 1.5 lb. per square inch the jet condenser has the advantage over the surface condenser for practically any number of working hours per year. This is shown in the diagram, Fig. 3, which is of a similar nature to the previous two diagrams. The surface plant is in this case estimated to cost £1620 and the jet plant £1380. These two sums at 13 per cent. and 11 per cent. respectively represent fixed annual charges of £211 and £152 respectively, the difference in fixed costs in favour of the jet plant being thus £59. The air pump of the jet plant is estimated to require 15.7 horse-power, and therefore to cost 9.4d. per hour at full load, while the corresponding figures for the surface plant are 10 horse-power and 6d. The surface

* There is, of course, a possibility of direct leakage of air into the condenser or exhaust pipe from the atmosphere; this can take place either with a jet or a surface condenser.

* δ is the difference in temperature between the condensing water at discharge from the condenser and the boiling point of water at the pressure within the condenser. The value of δ is discussed in an article in THE ENGINEER of June 17th, 1910.

* See article in THE ENGINEER of June 17th, 1910, above referred to.

plant is, however, in this case estimated to cost 1.7d. per hour more than the jet plant for water pumping power, so that the difference between the running costs of the two plants amounts to $9.4 - (6 + 1.7) = 1.7$d. per hour at full load in favour of the surface plant.

Higher terminal pressures than 1.5 lb. with no cooling tower and with water at 60 deg. Fah. need not be considered, as obviously the jet plant will have the whole field to itself. Terminal pressures lower than 1.5 lb. per square inch are, however, often desired, and Fig. 4 shows the fields for the two condensing systems when the terminal pressure is 1 lb. per square inch. In this case the surface plant is estimated to cost £2085, and the jet plant to cost £1800. Taking 13 per cent. of the former and 11 per cent. of the latter sum, the difference in the fixed annual cost is found to be £73. As regards running costs the air pump of the jet plant is estimated to require 28.4 horse-power, and therefore to cost 17.0d. per hour at full load, while the corresponding figures for the surface plant are 11.4 horse-power and 6.8d. Allowing for a difference in

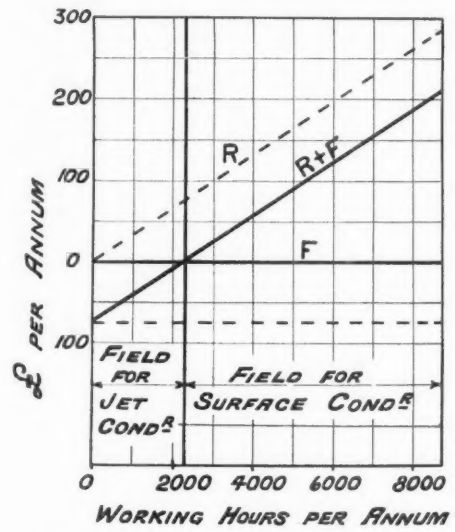


Fig. 4—Inlet temp. of circ. water 60 deg. F. Terminal pressure at turbine 1.0 lb. per square inch abs.

cost of water pumping power of 2.4d. per hour in favour of the jet plant, the difference in running costs is 7.8d. per hour in favour of the surface plant. The jet plant has in this case, compared with the previous case, a very limited field—only up to 2246 hours per annum—and for lower terminal pressures than 1 lb. per square inch its field would be still further restricted.

INSTITUTION OF MECHANICAL ENGINEERS.

LAST Friday evening an ordinary general meeting of the Institution was held at Storey's-gate, St. James's Park, when two papers were read and discussed. The first paper was entitled "The Production of Castings to Withstand High Pressures," the authors being Professor H. C. H. Carpenter and Mr. C. A. Edwards, both of Victoria University, Manchester. An abstract of this paper will be printed in a future issue. The second paper was by Mr. Andrew McCance, of Glasgow, and was entitled "The Constitution of Troostite and the Tempering of Steel." This paper is not reprinted, as its highly specialised character renders it of but little practical interest to the engineer.

Mr. J. A. F. Aspinall, the president, was in the chair, and in opening the meeting he announced that Mr. H. A. Ivatt found himself unable to accept the position of vice-president offered him on a vacancy occurring through the death of Mr. Graham Harris, and that Mr. H. F. Donaldson, C.B., chief superintendent Ordnance Factories, Royal Arsenal, Woolwich, had been offered, and had accepted the position. Professor Carpenter then presented his paper in a synopsis. In his conclusion he said he had to thank the Council of the Institution for the financial assistance which they had accorded him towards carrying out the experiments dealt with in the paper. Every penny which he required and asked for had been furnished without demur. When it was remembered that on the average the mouiding, machining, and testing of each casting meant about 15s., and that in all about 200 such castings were made, it would be understood that the investigation had not been at all economical.

Mr. Aspinall, in opening the discussion, said that in 1891 his staff had undertaken an extensive series of tests at Horwich with regard to aluminium bronzes, and that they had met with considerable trouble just as the authors had done in the earlier part of their work, but that they had not been able to overcome them in a similar manner. He also drew attention to the large headers employed by the authors for such small castings, several of which as cast and after machining and testing were on view at the time of the meeting.

Mr. Leonard Archbutt was the first speaker. He thought the paper was an excellent example of how a practical problem could be attacked from the scientific standpoint. Professor Carpenter had said that the work was not economical, but the speaker held that the wrong word had been used. The experiments might not have been cheap, but they were certainly not uneconomical, as the results established were of direct practical utility. The paper showed the necessity for attention to small details in the production of an alloy casting, and emphasised the importance of scientific supervision in the foundry. Passing to a criticism of the paper, he expressed his surprise at finding that the authors had commenced their researches with an alloy containing so much tin. A gun-metal with 15 per cent. of this constituent was a very brittle material. He had found in working with such a composition that the castings were very porous, and he had come to the conclusion that such porosity was due to the absence of the δ constituent, which had contracted into other parts of the castings. On the Midland Railway they had made an alloy containing 89 per cent. of copper, 9 per cent. of tin, and 2 per cent. of lead. It was found to have a maximum strength of 13.7 tons per square inch and an elongation of 10.05 per cent. These figures referred to the material if cast without phosphorus. If this element were added in such quantities as to leave in the final casting about 0.03 per cent., the strength was 16.25 tons and the elongation 23.25 per cent. The increased strength and elongation were, he thought, due to the greater soundness of the casting brought about by the addition of the phosphorus. With a material containing copper 87 per cent.. tin 9 per cent., lead 2 per cent., and zinc 2 per cent., they got nice castings a strength of 14.5 tons per square inch and an elongation of 12.45 per cent. Such materials as these, he said, would have formed a better basis for the author's experiments. Mr. Archbutt also spoke of the influence of quenching on the toughness of gun-metal. By quenching their D slide valves at temperatures above 500 deg. they found that whereas one blow from a height of 8ft. was sufficient to crack an unquenched casting, it required four such blows to start a crack, and perhaps nine to break the valve completely if it had been previously quenched as soon as it was taken from the mould. He had to record, however, that such quenched valves did not wear so well as the unquenched, but added that such quenching did not affect in any way either the tensile strength or the elongation of the material.

After Mr. Archbutt had spoken, the discussion threatened to terminate. Mr. Aspinall tried to persuade the representatives of certain firms who he knew were present to come forward, but his appeal failed to produce the desired result. At length Mr. Bateman came forward with a few questions and remarks. He asked the authors what fluid they had used in the pumps to get such a pressure as 20 tons to the square inch. Up to 3 or 4 tons water might be used, but for such high pressures he thought oil or other liquid had been employed. He stated that phosphor bronze would stand a working pressure of, say, 3 tons per square inch for a very long time without showing any signs of giving way, but that gun-metal could only stand such a continued pressure for a few weeks, and he suggested that it deteriorated in some way, probably due to fatigue.

Mr. H. F. Donaldson commented on the author's conclusion that to obtain satisfactory castings free from dross or scum the metal must be poured very slowly. If the formation of the dross were due to the oxidation of the aluminium, it appeared to him that it might be avoided by pouring the metal very quickly, so as to give the oxide no time to form.

Mr. E. A. Rainer asked the authors if there would be any advantage in using more than one runner for the mould, and remarked that if the metal had to be poured as cold as the authors recommended, there might be difficulty in getting it to follow the mould.

Mr. Harrison said that, as a manufacturer, he had to work under different conditions from those of technical college professors, for he had to work to specifications. The authors had used a hard gun-metal having an ultimate strength of 19 tons per square inch and an elongation of 3 per cent. on 2in. If he submitted such an alloy for Admiralty work the overseers would reject it, for they required at least 3½ per cent. elongation. With regard to the bronzes containing aluminium he could not say much as he had had little experience with them, but he knew that one of his foremen had complained that they quickly made his saws blunt. His greatest trouble with gun-metal was the conflicting requirements of soundness and tensile strength. To get the castings sound he had to sacrifice their strength. If he got them strong then they were porous. The influence of temperature was great, and a sound casting and a strong casting could not be produced at the one temperature. The president had spoken about the large heads employed by the authors, and, commenting on this, Mr. Harrison said that he had recently found that in some castings he had to make a quantity of metal, representing five times the finished weight of the castings, had to be melted.

Mr. C. A. Edwards, the joint author of the paper, then replied to the various speakers. Taking the question of big heads first, he said that it was far better to use a big head and get a good casting than to get a succession of three or four bad castings. It resolved itself down into a question of the relative economy of re-melting the heads or re-melting several bad castings. With regard to the point raised by Mr. Archbutt about quenching the castings, he remarked that this phenomenon had been known to the Chinese for several thousand years, and that such articles as gongs were regularly made by them in this manner. The increase in toughness could be explained by the fact that above 500 degrees the β constituent decomposed into the α and the δ. The δ constituent was quite brittle, so that if the casting were cooled slowly the brittle δ material was obtained, while if quenched the material was in the tough β condition. They had employed a 15 per cent. alloy, because such a material had been represented to them as possessing a suitable commercial composition. Replying to Mr. Bateman he said that both oil and water had been used to obtain the pressures in the tests. For the high pressures the castings were filled with water, and the pressures were pumped up with either oil or glycerine. They had tried pouring the metal quickly as Mr. Donaldson had suggested, and it was to this reason that they ascribed the large number of bad castings in the earlier part of their experiments. In most other metals the oxide which formed rose to the surface, but with aluminium bronzes the skin of alumina would not rise, nor would it unite, and as it surrounded portions of the metal like a cover it prevented such portions from joining up. Indeed, the conclusions come to by Professor Carpenter and himself showed that to secure a good sound casting a drop of metal had to be run into the mould and allowed to cover itself with its alumina coating. Then, as it might be put, additional metal had to be poured into the original drip in such a way that this skin was not broken, so that what really took place was that the original drop of metal was blown up or inflated until it filled the entire mould. The skin had not to be broken but allowed to grow slowly. Replying to Mr. Rainer, he had to say that if a flat casting were being made, say a plate, it would be distinctly advantageous to have several runners, but otherwise it did not much matter how many were used. Mr. Harrison had spoken about the difficulties manufacturers had to face in working to specifications. But he did not think that Professor Carpenter and himself had shirked any of these in planning their experimental investigations. Indeed, they had set out with the determination to produce castings capable of standing a pressure of 7 tons per square inch in excess of that ordinarily required in workshop practice and they had succeeded. Regarding large heads, it was to be borne in mind that the metal represented in them was not wasted, but could be melted again.

The president then called upon Mr. McCance to read his paper on the "Constitution of Troostite." The author presented it in abstract, and the only one to take part in the discussion was Mr. C. A. Edwards, the former speaker. Mr. McCance having replied, the meeting was about to terminate when Dr. Hele-Shaw arose to make a suggestion for the consideration of the Council. He said that he was quite sure Mr. McCance's paper was a valuable one, yet he confessed that he had not understood it, and he believed he was not alone among those present in this respect. They had heard what appeared to be an interesting discussion proceeding between two experts, yet they had been unable to follow it or take part in it. The Institution of Mechanical Engineers was not a body for the study of metallurgical subjects, and in view of this he suggested that the Council would do a popular thing if they would arrange for a lecture to be delivered dealing with the present state of knowledge regarding carbon in iron. He felt sure that most of the members would welcome such an addition to their knowledge.

No reply was given to Dr. Hele-Shaw, and on the president's announcing that the next meeting would be held on January 20th, when Mr. Dickson, of Glasgow, would read a paper on "The Electric Equipment of Docks," the proceedings terminated.

THE EXPLOSIBILITY OF COAL DUST.

No. III.*

THE experiments described in our previous article being regarded by the committee as affording a sufficient demonstration of the fact that coal dust when raised as a cloud in air, and in the entire absence of fire-damp, is explosive, it was decided to prosecute researches to test the value of certain remedial measures which had been suggested. Among these the most likely seemed to be Mr. Garforth's suggestion, which was to the effect that a coal dust explosion could be checked if along with the coal dust an incombustible dust, such as stone dust, were present in sufficient quantity. Mr. Garforth had come to this conclusion in 1886, as the result of his observations during the recovery of the Altofts pit, after the explosion which took place there in that year.

During 1908 preliminary experiments were carried out at Altofts, and it was shown sufficiently clearly that stone dust did possess the quality attributed to it by Mr. Garforth. It was accordingly decided to make preparations for investigating the question much more thoroughly in the following year, and to appoint a trained chemist and physicist to assist the committee in the work. Mr. R. V. Wheeler, D.Sc., was appointed to the post, and along with Mr. Horace Darwin, of the Cambridge Scientific Instrument Company, began the designing of the instruments required for the more accurate work about to be undertaken. A specially equipped laboratory was at this time erected on the site at Altofts, where many questions relating to the effect of heat on coal dust and other problems have since been studied.

We do not propose to describe this laboratory, nor will we dwell on the details of the methods adopted for sampling and analysing the coal dust. Such details, while admittedly of the greatest importance to the accuracy of the investigations, are not of general interest, and those who desire to acquaint themselves with them are advised to consult the volume itself. We may, however, state that stress is laid in the report on the necessity for adopting uniform methods of sampling and chemical analysis, so that true comparisons may be drawn between the results of different workers, or of the same worker at different times. After certain preliminary work, in which it was shown that different methods of analysis yielded comparatively widely varying results with the same sample of coal, standard systems were adopted at Altofts laboratory, and these have been adhered to since. Before passing from this subject, we may remark that the question soon arose as to whether the degree of fineness of the dust had any influence on the chemical analysis, particularly with reference to the contents of moisture, volatile matter, and ash. Investigations were undertaken to settle this point, and it was discovered that the dust yielded results apparently dependent upon its state of division. Thus, the average percentage of moisture in dust which had passed through the 240 mesh was 3.22; while the coarser dust passing through a 100 mesh and remaining on a 150 mesh had 3.12 per cent. of moisture. The volatile matter was found to be greatest in the coarse dust, and to descend in its percentage as the dust got finer. The ash content, too, varied consider-

* No II. appeared December 16th.

ably with the state of division of the dust, but followed no definite rule. It was thought, however, that all these differences were too great to be accounted for solely by the degree of fineness, and further work was carried out, as a result of which it was definitely shown that the differences were due to an actual difference in the chemical composition of the dust coming from the various sieves. Thus, those parts of the coal less easily pulverised than the others have a distinctly different percentage composition. To secure uniformity of results, it was therefore necessary to choose one particular degree of fineness for the dust analysed, and in view of the fact that that dust which passes a 240-mesh sieve constitutes about 75 per cent. of the dust used in the experiments, this degree of fineness was taken as the standard for the purposes of analysis.

Of the many elaborate and beautiful instruments specially designed for the British coal dust experiments we cannot here enter into a description. They are all clearly described and illustrated in the volume before us, and to it we refer those of our readers who may desire to follow out the experimental details. We may, however, outline the functions, if not the designs, of the instruments. In order to study the fundamental features of a coal dust explosion, data are required concerning (1) the pressure developed; (2) the velocity with which the flame and the pressure are propagated; (3) the composition of the products of combustion; and (4) the temperature attained during explosive combustion. With regard to the measurement of pressure, the exceptional conditions of the experiments render all ordinary methods of measuring this quantity of no avail. Pressures as high probably as 300 lb. per square inch are developed in a fraction of a second, and while it is fairly easy to design apparatus to indicate the maximum pressure, the difficulties introduced by the inertia of the moving parts are very great when it is sought to record continuously the varying pressures at any one point in the gallery. However, an ingenious manometer fitted with a recording drum has been designed, and by employing such instruments at different points in the gallery a complete record of the development of the explosion as far as the pressure is concerned becomes obtainable. These instruments are worked in conjunction with two distinct electrically-operated recorders, the first of which indicates by a mark on the drum paper the exact instant at which the explosion commences, while the second makes two marks on the paper at an interval of a tenth of a second, so that the precise rate of rotation of the drum in each case can be determined. In this way the passage of successive waves of pressure along the gallery can be readily studied. As the charts obtained from the manometers are on a very small scale as regards the pressure ordinates, a delicate microscopic measuring apparatus has been designed, so that larger diagrams can be reproduced. We may say that by these means an interval of time less than $\frac{1}{5000}$ of a second can be accurately measured on the chart.

To measure the velocity of the flame along the gallery electrical circuits, including a recording appliance outside the gallery and a tin-foil element inside, were established. The passage of the flame fuses the tin-foil elements and the successive breaks in the circuits are recorded on the chronograph. The recording chronograph is, of course, electrically operated, and the same instrument serves all the circuits. This necessitates the use of some form of switch, and accordingly an automatic commutator of special design has been constructed. The use of this commutator has the additional important advantage in that only one electro-magnet is employed for recording each break instead of one for every circuit. Thus difficulties due to "time lag" in the magnets are entirely avoided, for, as is well known, the time lags of similar magnets differ slightly, but to a sufficient extent to interfere with very small measurements such as are made in these experiments. With these appliances, it is stated, it is possible to record velocities of as much as 3000ft. per second between successive points 50ft. apart. A second form of circuit-breaker dependent for its action on the movement of a piston has also been designed, and by its use the rate of travel of pressure along the gallery can be measured. In order to study the composition of the products of combustion two different styles of sampling apparatus are used. In one of these a small bottle is employed, and the gases it contains after an explosion are subjected to chemical analysis. The second sampling device includes a cylinder whereby a fairly large quantity of the gases can be trapped. This device affords a sufficient supply for testing the physiological effects of the gases on animals. Both these samplers are put into operation by the explosion itself. To bring this about they are arranged in connection with electrical contact makers, which depend for their action either on the movement of a spring-loaded piston by the pressure, or on the fall of a small bridge into mercury cups, the bridge being previously kept up by an electro-magnet, which is supplied with current as long as a strip of tinfoil is in existence in its circuit. In the first case, therefore, the pressure of the explosion makes the contact; in the second, the flame, by fusing the strip of tinfoil, makes the contact. In either case the completion of the electric current fuses a wire which sets the samplers into action. As regards the measurement of the temperature of the explosion, it would appear that considerable difficulty has been found in devising an instrument to suit the exceptional circumstances of the experiments. By employing platinum resistance thermometers, however, the difficulty is being surmounted.

We will now pass to the description of the experiments with stone dust. Both as a preventive of the primary ignition, and as a means for checking an explosion when once under way, stone dust, it would appear, has yielded encouraging results. With regard to the employment of stone dust as a means for checking an explosion, it is obvious that each stone dust experiment has to be accompanied by one in which the stone dust is absent. To ensure comparable results, the coal dust zone in each experiment must occupy the same length of the gallery. In other words, if a coal dust zone 275ft. in length is being used with a stone dust zone of 150ft. in front of it, the results must be compared with another experiment in which a similar length of coal dust zone occupies a similar position, but with a dustless zone of 150ft. in front of it. The exact position of the coal dust zone has, of course, a great influence on the pressure, &c., developed at any given point in the stone dust or dustless zone.

In Figs. 9 and 10 we reproduce the diagrams relating to experiments 55 and 57. No. 55 is a "dustless"

Fig. 9—DUSTLESS EXPERIMENT

experiment, and is to be compared with No. 57, which is a "stone dust" example. Referring to No. 55, it will be seen that the coal dust zone, 275ft. in length, started 150ft. in from the downcast, and ended at 425ft. The first 150ft. of the gallery was free from dust. Sixty thousand cubic feet of air were circulating through the gallery per minute at a velocity of 1450ft. per minute. The coal dust was obtained from Silkstone coal, and was spread on the shelves, &c., at the rate of 1 lb. per linear foot, or 0.4 oz. per cubic foot of air space. The igniter was charged with 24 oz. of powder, and the small cannon with 4 oz. On the explosion taking place the flame shot out 16ft. from the downcast—or a total distance of 166ft. from the beginning of the coal dust zone—all the props were blown down, the tub placed 6ft. from the mouth of the gallery was hurled to a distance of 600ft., and valve

Fig. 10—STONE DUST EXPERIMENT

No. 10 was blown out to 182ft. Referring now to Fig. 10, it will be seen that in experiment No. 57, the previously dustless zone was strewn with stone dust, but that otherwise the conditions of the experiment were unaltered. The stone dust was spread at the rate of 15 lb. per linear foot, and was dispcsed partly on the shelves and partly on brattice cloth placed near the roof. The explosion from this experiment sounded very violent, the tub was thrown to a distance of 372ft., and valve No. 10 was blown out 180ft. But no flame issued from the downcast, and on examining the tufts of cotton wool placed every few feet along the gallery, it was found that the flame had penetrated only 55ft. into the stone dust zone. Neither the analysis and fineness of the coal dust nor the meteorological conditions were exactly similar in these two experiments, but they corresponded sufficiently closely to be of little importance in affecting the results.

At A, 100ft. from the commencement of the coal dust zone, and at B recording manometers were placed. In the committee's record the curves obtained from these instruments for the above two experiments are given. A study of these shows that the maximum pressure recorded at B was in each experiment 43 lb. per square inch, and that both curves are very nearly similar in shape From this it may be assumed that the degree of similarity aimed at in the conditions was satisfactorily attained. On the other hand, the curves from the manometer at A are widely different. While the maximum pressure indicated here during the dustless zone explosion is 100 lb. per square inch, that for the stone dust experiment is only 30 lb. It will therefore be seen that the stone dust had a material influence in checking the explosion.

In experiments 58 and 62 a coal dust zone of the standard length, 275ft., was arranged in the same position as employed in Nos. 55 and 57. For 50ft. from the mouth of the gallery, coal dust was also in each case strewn on the shelves, &c. The intervening distance of 100ft. was in experiment No. 58 strewn with stone dust, and in No. 62 was left dustless. Thus it was possible to determine whether the stone dust would prevent the explosion leaping a distance of 100ft. The record of experiment No. 58 shows that the flame penetrated for 54ft. into the stone dust zone, and did not ignite the second coal dust zone. Valve No. 10 was blown out 225ft., and the tub was thrown 504ft. from the downcast. In experiment No. 62 the flame not only leapt the dustless zone, but ignited the short coal dust zone, and issued from the mouth of the gallery for 100ft. In this case valve No. 10 was again blown out, and the tub was hurled 528ft. from the downcast. The manometer placed at B in the stone dust experiment showed a maximum pressure of 31 lb. per square inch, the corresponding

Fig. 11—SANDWICH EXPERIMENT

reading for the "dustless" experiment being 39.5 lb. On the other hand, the manometer at A indicated for the stone dust experiment a maximum pressure of 17.5 lb. as compared with 84 lb. in the "dustless" experiment.

These experiments, and others of which they are typical, were designed to test the efficacy of a stone dust zone in checking an explosion travelling towards the downcast, that is to say, against the direction of the ventilating current. Others were carried out wherein a coal dust zone was sandwiched between two stone dust zones, so that the influence of the ventilating current in assisting or retarding the checking action of the stone dust could be studied. Experiment No. 116 is a good example of this class. Starting from the downcast, there was first a coal dust zone 50ft. in length, then 100ft. of stone dust. This was succeeded by a coal dust zone of 375ft., and for the remaining portion of the gallery a stone dust zone of 75ft. —see Fig. 11. It was found after the experiment that the flame had penetrated for 22ft. into the stone dust zone towards the downcast, and for 46ft. towards the return. The B manometer chart shows a maximum pressure of 34 lb., the A manometer showing 10 lb. We would point out with regard to this experiment that the effect of the ventilating current in partially overcoming the checking action of the stone dust is probably exaggerated. From Fig. 11 it will be seen that the igniter was not arranged centrally with regard to the central zone of coal dust, and its position, only 100ft. from the return end of this zone, naturally tends to upset a strict comparison. On the other hand, the ignition cannon pointed towards the downcast, and this must also have influenced the equality of propagation of the explosion; but it may be assumed that this influence would be opposite to that exercised by the unsymmetrical position of the cannon.

We have now dealt with the subject of stone dust as a means for checking coal dust explosions when once under way. We have yet to describe the experiments made at Altofts, with a view to seeing how far stone dust may be employed as an agent for preventing the start of such an explosion.

The conditions assumed in experiment No. 63 were

that in a mine two shots might be fired within a few seconds of each other, the first shot taking the ordinary course, and raising a cloud of dust by its concussion, while the second shot was to be a blown out shot, which, throwing out the tamping, would be responsible for the projection of a large flame into the cloud of dust raised by the first shot. The cloud raiser, of course, represents the normal shot, and the igniter the blown-out shot. The cannon were arranged 90ft. apart, and between them, and for 60ft. beyond each, the gallery was strewn with stone dust. A coal dust zone succeeded this stone dust zone at each end—see Fig. 12. As much would appear to depend on the degree of fineness both of the coal dust and the stone dust, we give below the figures relating to the two constituents. The air current had a

Degree of Fineness of Coal and Stone Dust.

	Coal dust, per cent.	Stone dust, per cent.
Remaining on 100 mesh	4·0 ...	67·5
Through 100 on 140 ,, ...	8·0 ...	12·0
,, 150 on 200 ,, ...	3·0 ...	4·0
,, 200 on 240 ,, ...	7·0 ...	3·0
,, 240 and finer	78·0 ...	13·5

velocity of 1200ft. per minute, so that it is to be expected that by itself it raised a considerable quantity of coal dust from the floor and sides, although it is probable that it could not raise the heavier stone dust. As soon as the fan doors were closed, therefore, the air in the immediate vicinity of the igniter would be charged with coal dust. On the cloud raiser being discharged a cloud of stone dust would rise and mingle with the coal dust in suspension in the air. But

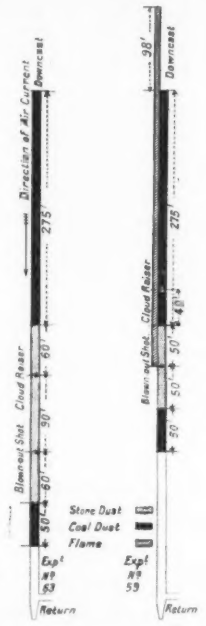


Fig. 12—COAL AND STONE DUST EXPERIMENTS

on the igniter being fired there was no explosion, the presence of the stone dust having rendered the coal dust harmless. In experiment No. 59 the igniter was again surrounded by a stone dust area, but the cloud raiser was fired within the coal dust zone. This resulted in a cloud of undiluted coal dust being carried past the igniter, and, as had been expected, an explosion resulted, as indicated in the second diagram in Fig. 12. From these experiments

Experiments with Mixtures of Coal and Stone Dusts.

Experiment No.	Mixture. Coal dust.	Mixture. Stone dust.	Quantity of mixture per cu. ft. of air space.	Maximum pressure recorded.	Result.
	p.c.	p.c.	oz.	lb.	
81	100	nil	0·2	11	Explosion: flame projected 130ft. from downcast
80	90	10	0·2	none	Inflammation only; flame travelled 110ft. in front of point of ignition
82	90	10	0·4	4·5	Explosion; flame projected 130ft. from downcast
84	80	20	0·4	none	Inflammation only; flame travelled 80ft. in front of point of ignition
112	80	20	0·6	8·9	Explosion; flame projected 130ft. from downcast
87	70	30	0·6	none	Inflammation only; flame travelled 63ft. in front of point of ignition
89	70	30	0·8	8	Explosion; flame projected 150ft. from downcast
90	60	40	0·8	none	Inflammation only; flame travelled 165ft. in front of point of ignition
92	50	50	1·0	8·4	Explosion; flame projected 165ft. from downcast
93	50	50	1·0	none	No explosion; evidence of flame near cannon up to 10ft.

it can be concluded that the occurrence of a blown-out shot in a stone dust zone will not cause an explosion of the dust coming from a neighbouring coal dust zone unless some exceptional circumstance causes an excessive amount of coal dust to be carried past the blown-out shot.

A second and more important series of experiments on the same subject, namely, the power possessed by stone dust of preventing a coal dust explosion, now falls to be recorded. In these experiments a mixture of stone and coal dust was strewn on the shelves, bars, props, &c., of the gallery for a length of 275ft. from the downcast. Ignition was effected by a 24 oz. charge in the large cannon, which was placed at the return end of the dust zone; the volume of air passing through the gallery at the time of the experiments was 60,000 cubic feet per minute. The coal and stone were brought to the same degree of fineness and intimately mixed in a disintegrator. It will be seen from the table above, which shows the results of these experiments, that as the series progressed two quantities were varied, namely, the percentage composition of the mixture and the quantity of mixture used per cubic foot of air space in the gallery. These results are worthy of the closest attention. The general conclusion to be drawn from them is that as the percentage of incombustible dust is increased so must the total quantity of mixture per cubic foot of air be augmented, in order that the flame may be propagated with explosive violence, while when the dusts are present in equal proportions the flame is not propagated even with a large excess of the mixture.

We have now concluded our summary of the British coal dust experiments as far as carried out up to the present. The account is necessarily incomplete, but we have said enough to show the magnitude and importance of the problems being worked out, and the success which has already attended on the efforts of the Mining Association's Committee. The report from which we have abstracted the information contained in this and the preceding article constitutes by itself a most valuable production, and should be in the hands of every mine inspector and colliery official in any way responsible for the health and safety of the men working beneath the surface. We have not been able to present a synopsis of it in anything like a full degree. Indeed, to quite half of its contents we have made no reference whatever. Those parts which we have thus omitted contain, among other matter, a close and scientific study of the mode of propagation of coal dust explosions, a chapter on the application of stone dust at Altofts Collieries, and accounts of certain laboratory and microscopical investigations carried out in the course of the main experimental work. The work of the committee is, as we have already pointed out, not yet completed, but we think that sufficient has already been done to warrant the closest attention from the mining world in general. The further results will be awaited with no less interest, and when the work has been completed we should be in possession of a vast amount of fresh knowledge regarding the many complex phenomena associated with the explosion of coal dust.

BUILDING OF THE NEW CANADIAN NAVY.

THE Dominion Government have announced from Ottawa that contracts for the proposed ships to form the beginning of a Canadian navy will be fixed in the near future. It is understood that six British shipbuilding firms have been invited to tender for the new construction, and offers have been made by some Canadian firms to undertake the work. The tenders at present asked for are for four cruisers, presumably of the Bristol type, and six destroyers. It is stated that the contracts for all of the ten vessels will be entrusted to a single contractor, and the reason for this is probably the decision of the Ottawa Government that all of the vessels must be built in Canada.

The question at once arises—Where are they to be built? Already there are rumours that point to Vancouver, on the Pacific coast, as destined to be the favoured locality. It is situated on the finest natural harbour of Canada, and the construction of a large dry dock is to be immediately proceeded with there. Proposals are also on foot for building a floating dock capable of lifting ships of 15,000 tons displacement.

The Pacific coast offers very many attractions to a shipbuilder. Its harbours are as fine as any on the Atlantic coast, and facilities for obtaining material are good. Coal and iron are obtainable at the very door, and if requisite capital to erect adequate smelting works and rolling mills were forthcoming, the business of steel shipbuilding, which has already reached respectable growth, would receive a tremendous incentive. If it be true that the new Canadian navy is to be built at this port, its future as a shipbuilding centre is assured. The coasting trade alone provides a considerable amount of repair work, much of which is at present diverted to other ports from lack of docking accommodation. Such firms as Harland and Wolff, Swan, Hunter, and Wigham Richardson, and others have had representatives on the spot making investigations as to the possibilities of development along these lines.

Vancouver has one decided advantage over Atlantic ports in its Pacific slope climate, which would render the business of shipbuilding possible all the year round. Burrard Inlet, upon which it stands, seems to possess all the requirements which appeal to the professional and business instincts of the shipbuilder. It is an ideal site for the purpose. The harbour is magnificent, being landlocked, and therefore quite sheltered. Within the First Narrows, known as the Lion's Gate, the shore of the harbour proper, not including the north arm of Burrard Inlet, extends 25 miles, while the width is 2¼ miles. The low-water depth at the wharves is 26ft., and in the stream about 30 fathoms. The average rise and fall of tide is 13½ft. At low tide the present entrance to the harbour has a width of 700ft. at its narrowest point. It is, however, to be widened to 1200ft., and dredged to a uniform depth of 30ft. to 35ft. at dead low water. A contract has been placed by the Dominion Government for a special dredger to do this work, which will be completed, it is estimated, in about three years, including the removal of some shoals and a projecting reef. At the wharves of the shipbuilding business at present in operation there is a depth of 30ft. of water at low tide, so that war vessels could be afloat at all times.

Burrard Inlet, then, needs little artificial improvement to make it suitable as a shipbuilding centre, whether for warships or merchant vessels, and it is likely to be a strong, if not the strongest, competitor for the construction of the new Canadian navy. Indeed, the site at North Vancouver, upon which large shipyards are to be erected in the near or more distant future, is practically settled; it is on the north shore of the inlet, where there is plenty of deep water close in shore. The Imperial Dry Dock and Shipbuilding Company has been granted a subsidy from the Dominion Government, and Roche Point has been selected as the site of a new dock. Victoria, 84 miles from Vancouver, has at present the lead in shipbuilding when compared with Vancouver, and has turned out such vessels as the Princess Royal and Princess Beatrice, for the C.P.R. line. Notwithstanding this, Vancouver appears from its natural suitability for the purpose, destined to become the largest shipbuilding and commercial centre on that part of the Pacific coast. It possesses with the minimum of expenditure, a harbour such as many seaports cannot secure at any price. The only shipbuilding now carried on there of any importance is on quite a small scale, but it is up to date so far as it has gone, and although the larger of the two firms employs less than a hundred hands, and it is of quite recent establishment, it is intended to be the nucleus of a much larger concern.

There are large coal deposits in the immediate neighbourhood; a new mining corporation called the Canadian Collieries Company, has recently acquired an immense coalfield on Vancouver Island, and has devoted three million dollars to opening up and developing of new mines on their property, and to increasing the output of those already in operation. Mechanical haulage, by means of electric power, generated by a 50,000 horse-power waterfall will be installed, and this source of power will at the same time supply other affiliated businesses.

The beneficial effects of this progressive policy will be felt by all business men in the district, for all need coal; and specially is it important if Vancouver is to become an important shipbuilding centre. The possibilities of early development in this district has been foreseen by many notable British firms. Cammell, Laird and Co., for instance, do a large trade with the various mining companies and manufacturers of the province. Stamps, dies, high-speed tool steels, hollow-drill steels, nickel steel, and other specialities of the firm, are supplied in large quantities through the resident agent in Vancouver.

It is a trite saying, that progress of trade in a seaport is infallibly indicated by the appearance of the wharves on the water front, and this port is no exception. Her rapidly extending wharfage is generally in a more or less congested condition. In the Vancouver service, Messrs. Alfred Holt and Co., of the Blue Funnel line as it is termed, maintain a fleet of eight fine vessels. The C.P.R. steamers, and the Andrew Weir line, both run constantly between Vancouver and the Orient. The Canadian-Australian mail service to Sydney is carried on by the Union Steamship Company of New Zealand, and a large cargo business is done with goods from the Atlantic coast and Europe, which are transported across the Isthmus of Tehuantepec by the railway from Puerto-Mexico, to Salina Cruz, and thence re-shipped to ports on the Pacific Coast. This latter route is so much cheaper than the trans-continental railway freight, that a consignment of goods from, say, Montreal to Vancouver would be carried *viâ* the Isthmus for little more than half the overland railway freight across the Continent.

Five years, or even three years ago, export of Canadian grain from Vancouver was a dream only entertained by one or two far-seeing and optimistic individuals. About two years ago the probability of Vancouver becoming a great factor in the shipment of grain from Alberta and Saskatchewan began to attract attention, and to-day she is a grain-exporting centre whose output is only limited by the present dimensions of the demand for Alberta wheat. When the Panama Canal is opened there will probably be a great deflection of the present eastward flux of wheat from Alberta, Saskatchewan, and Manitoba to the western route *viâ* Vancouver, with a very considerable saving of time as compared with the lake route. Vancouver harbour is open and free from ice all the year round, and great things are expected of the A.B.C. route —Alberta British Columbia—as a great exporting channel for Canadian grain.

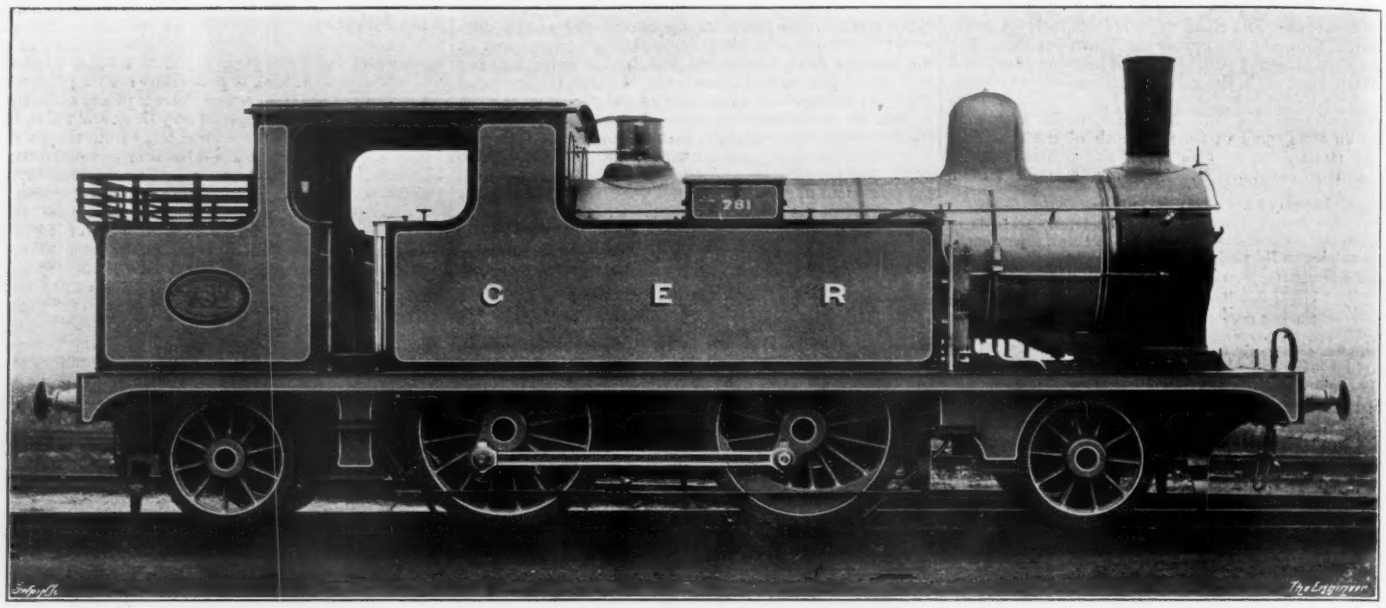
The growth of the railway systems of British Columbia is commensurate with expansions apparent in other directions, and Vancouver is fast becoming one of the biggest railway centres on the Pacific coast. The question is, will its natural advantages cause it to become the chief seaport of that Coast? Basing judgment on its geographical and terminal position, it appears probable that it will. For nearly twenty years the C.P.R. was the only railway entering the city. The Great Northern and the Northern Pacific came later, giving an example likely to be soon followed by others. Three years will see the Canadian Northern connection complete with the East. The Grand Trunk Pacific has engineering parties in the field, with Vancouver as the main objective, and its line will probably be completed within five years. Other subordinate lines are also in construction.

All this goes to show that the Dominion Government have every reason to favour Vancouver as a likely position for building and equipping their new navy. By the time the first instalment of it is in being, there will be a valuable national asset to protect there, and one can easily imagine how strong an appeal such a natural harbour as Burrard Inlet must make to both the technical and strategical components of the Dominion Government.

THE INSTITUTION OF NAVAL ARCHITECTS.—The Institution of Naval Architects, which was founded in 1860, has received an intimation from the Lord President of the Privy Council to the effect that H.M. the King has been pleased to approve the grant to it of a Royal Charter of Incorporation.

FOUR-COUPLED TANK ENGINE, GREAT EASTERN RAILWAY

MR. S. D. HOLDEN, STRATFORD, ENGINEER



PASSENGER TANK ENGINES.

No. VI.*

THE Great Eastern Railway Company conducts an enormous suburban traffic over a very large district, extending indeed as far as Southend, the company having running powers over a portion of the London, Tilbury and Southend line, a distance of about 42 miles. The growth of the traffic led Mr. James Holden, some years ago, to plan new third-class coaches, which carry six on each side, instead of five, thus avoiding the use of trains too long for the platforms. As expedition in starting these trains, which stop at almost every station, is essential rather than speed, a class of small-wheeled tank engine, six coupled, is used for the shorter runs, such as those to Loughton and Epping. For the longer runs a different and more powerful engine has been recently designed and put to work with great success by Mr. S. Dewar Holden, Chief Mechanical Engineer of the Great Eastern Railway, to whom we are indebted for the illustrations and particulars which we publish.

The general dimensions of these locomotives, which are known as the "791" class, are given below:—

Diameter of wheels—	
Leading	3ft. 9in.
Driving	5ft. 4in.
Intermediate	5ft. 4in.
Trailing	3ft. 9in.
Wheel base—	
Leading to driving	7ft. 6in.
Driving to intermediate	8ft.
Intermediate to trailing	7ft. 6in.
Extreme centres	23ft.
Cylinders—	
Diameter	17½in.
Length of stroke	24in.
Centres	2ft. 4in.
Tubes—	
Number	231
Diameter, external	1⅝in.
Length, between tube plates	10ft. 6½in.
External heating surface of tubes	1034·8 sq. ft.
Heating surface of fire-box	98·4 sq. ft.
Total heating surface	1133·2 sq. ft.
Boiler—	
Working pressure	160 lb.
Description	Telescopic
Length of barrel	10ft. 2½in.
Diameter, internal	4ft. and 4ft. 1in.
Inside fire-box—	
Length, inside	4ft. 9in.
Width, inside	3ft. 2⅝in.
Area of fire-grate	15·3 sq. ft.
Fire-box shell—	
Width, outside	3ft. 11in.
Length, outside	5ft. 5in.
Distance between frames	4ft.

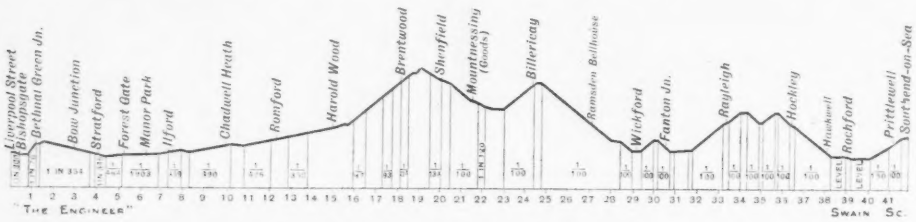
Average working weight of engines of this class—

	Tons	cwt.	qr.
Leading wheels	13	8	2
Driving wheels	14	17	3
Intermediate wheels	11	14	0
Trailing wheels	11	10	2
Total	51	10	3

Diameter of blast pipe top	4⅜in. and 5½in.
Coal	3½ tons
Water	1200 gallons
Adhesive weight	26 t. 11 c. 3 q.

* No. V. appeared September 23rd.

It will be seen that these are powerful engines which can do a great deal of hard pulling, the tractive effort, with an average cylinder pressure of 100 lb., being 11,500 lb., or over 5 tons. The grate area, 15.3 square feet, appears small, but it has been adopted as the result of long experience. The coal is very good and the speeds are moderate; in fact, all the proportions of the engine are the result of a careful recognition of just what is wanted, and how the want can be supplied most completely and efficiently.



PROFILE OF G.E. LINE, LONDON—SOUTHEND

We give the running schedules of two trains—one London to Witham, the other London to Southend:—

7.38 *p.m. Liverpool-street to Witham.*

Length of trip, 38¾ miles. Time on journey, 82 mins.

Formation of train—

Summer.	Winter.
Engine	Engine
Two firsts	Two firsts
One composite (1st and 3rd)	One composite (1st and 3rd)
Three seconds	Three seconds
Five thirds	Three thirds
Two brake thirds	Two brake thirds
One brake van	One brake van

Approximate weight, fully loaded, including engine—

Summer, 286 tons. Winter, 242 tons.

Running schedule—		p.m.	Miles.	Mins.	Miles per hour
Liverpool-street	dep.	7.38			
Ilford	arr.	7.53	7¼	15	29
	dep.	7.54			
Romford	arr.	8.3	5¼	9	35
	dep.	8 4			
Harold Wood	arr.	8.9	2½	5	30
	dep.	8.10			
Brentwood	arr.	8.17	3¼	7	28
	dep.	8.19			
Shenfield	arr.	8.24	2	5	24
	dep.	8.26			
Ingatestone	arr.	8.32	3½	6	35
	dep.	8.33			
Chelmsford	arr.	8.42	6	9	40
	dep.	8.44			
Hatfield Peverel	arr.	8.53	6¼	9	42
	dep.	8.54			
Witham	arr.	9.0	2¾	6	27½

We give a profile of the road, which is very heavy. It practically rises all the way to the top of the Brentwood bank, 19 miles from Liverpool-street. This bank is three miles long, and the gradient varies between 1 in 106 and 1 in 84. There are besides numerous inclines of 1 in 100; in fact, the line is a switchback. It will be admitted, we think, that to maintain 28 miles an hour up the Brentwood bank and an average of over 33 is an excellent performance.

8.51 *a.m. London to Southend (Summer only).*

Length of trip, 41½ miles. Time on journey, 83 mins.

Formation of train—

Engine.
Two firsts.
Two seconds.
Six thirds,
Two brake thirds.

Approximate weight, fully loaded, including engine, 312 tons.

Running schedule—		a.m.	Miles.	Mins.	Miles per hour
Liverpool-street	dep.	8.51			
Stratford	arr.	9.1	4	10	24
	dep.	9.3			
Ilford	arr.	9.10	3¼	7	28
	dep.	9.12			
Shenfield	arr.	9 32	13	20	39
	dep.	9.35			
Billericay	arr.	9.42	4¼	7	36½
	dep.	9.43			
Wickford	arr.	9.50	4½	7	38½
	dep.	9.52			
Southend	arr.	10.14	12½	22	34

We have only to add that these engines are very strongly built, with large wearing surfaces and wide water spaces. The intention is that they shall be as seldom as possible in the repair shops. We understand that they are fully realising all that Mr. Holden anticipated when he designed them.

THE PHYSICAL SOCIETY'S ANNUAL EXHIBITION.

THE sixth annual Exhibition of the Physical Society of London was held at the Imperial College of Science last Tuesday, when many interesting electrical, optical, and other physical apparatus were brought to our notice. In the afternoon and evening Professor J. A. Fleming lectured on "Some Recent Improvements in Transmitters and Receivers for Wireless Telegraphy," and Mr. R. W. Paul gave a number of cinematograph demonstrations of some physical phenomena. The following firms were exhibiting:—R. and J. Beck, Limited, the British Radio-Telegraph and Telephone Company, Limited, the Cambridge Scientific Instrument Company, Cassella and Co., A. C. Cossor, Limited, W. H. Cox and Co., Limited, Crompton and Co., Limited, J. H. Dallmeyer, Limited, Elliott Brothers, Everett Edgcumbe and Co., Gallenkamp and Co., Gambrell Brothers, J. J. Griffin and Sons, Hick and Co., A. Hilger Limited, the India-rubber, Gutta-percha, and Telegraph Works, Limited, Marconi's Wireless Telegraph Company, Leslie, Miller, Muirhead and Co., Nalder Brothers and Thompson, Negretti and Zambra, Newton and Co., R. W. Paul, W. G. Pye and Co., Strange and Graham, H. Tinsley, Towson and Mercer, the Western Electrical Instrument Company, Wright and Co., and Carl Zeiss. Invitations were given to the Institution of Electrical Engineers, the Faraday Society, the Optical Society, and the Röntgen Society.

Several interesting exhibits were shown on the stand of the Cambridge Scientific Instrument Company. Among other things there was a Brearley recalescence curve tracer, as illustrated in Fig. 1. This instrument is primarily intended for use with a thermo-couple and reflecting galvanometer for giving recalescence curves of steel, or cooling curves of any body, on a very open and accurate scale and with rectangular co-ordinates directly connecting time and temperature. The galvanometer scale forms part of the curve tracer, and is fixed just over a drum carrying a paper chart on which the record is traced. The drum makes one revolution in ten minutes. It is driven by an electro-magnet controlled by a clock. The pencil, which is depressed on the drum twice every second, is carried by a carriage which also has a pointer fixed to it. The carriage and pointer can be moved up and down the scale by means of a screw and hand wheel. When tracing a curve the only thing the observer has to do is to turn the hand wheel, so as to keep the pointer coincident with the moving spot of light. The drum takes charts 360 mm. long and 300 mm. wide, and as this width need only represent a few hundred, or even less, degrees Centigrade, it will be seen that the curve obtained is on a very open scale.

Another exhibit was in the form of a tilted gold leaf electrometer. This is shown in Fig. 2. It has a small capacity and high sensitiveness, which latter property is due to its ability to control the conditions under which a

freely hanging gold leaf is attracted out of the vertical by an inclined charge plate in its proximity. It is possible to secure either complete stability over the whole of the path of the leaf, or instability over part of it, and the user works as near as is expedient to the region where the conditions give the intervening infinitive sensitiveness.

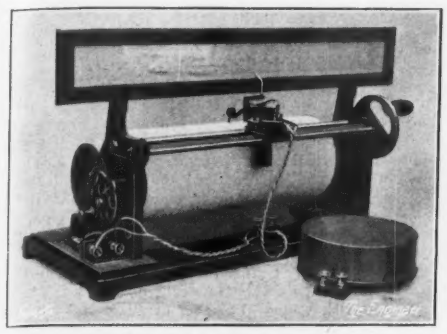


Fig. 1—CURVE TRACER

The leaf is contained in a metal case, and is observed by a microscope, the plate being maintained at a steady potential. At the Exhibition this apparatus was used for showing electrification due to the splashing of mercury.

The Ayrton-Mather galvanometer, illustrated in Fig. 3,

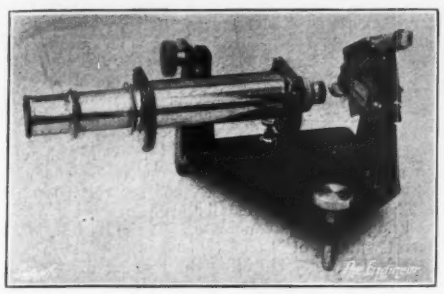


Fig. 2—ELECTROMETER

was also on view. This is of the firm's well-known pattern, in which the coil is separately mounted in a suspension tube, and is therefore easily removable, and can readily be interchanged for other coils if desired, It has an exceedingly light and compact coil, so that

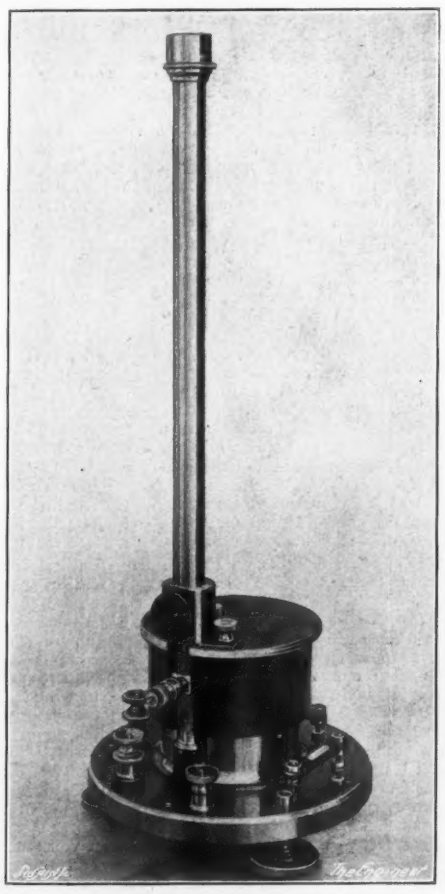


Fig. 3—GALVANOMETER

in order to secure a reasonably long period, the suspension strip has to be of much greater length than usual, *i.e.*, 290 mm. The standard resistance of the moving system is about 250 ohms, and has a free period of about 3 sec. The sensitivity obtained is about 740 m.m. per micro-ampère at a scale distance of 1m.

The company's bi-meter CO_2 recorder was also on view, and is illustrated in Fig. 4. This is a new pattern of CO_2 recorder, working on very simple and practical principles. It contains no absorbent liquids, the absorbent material used being dry lime. The gas flows through the instrument in a steady and continuous stream, and no valves are necessary. The main part of the instrument consists of two ordinary gas meters. The flue gases under test are first drawn through one of these meters, and then through an absorption chamber, in which the flue gases are freed from CO_2, and lastly through the second meter. It is evident that, due to absorption of the CO_2, the volume of gas passing through the second meter is less than that passing through the first, and the difference in volume represents the amount of CO_2 absorbed. The gas meters operate the recording pen through a differential gear arrangement, and cause it to rise at a speed dependent on the proportion of CO_2 absorbed. After a definite volume of flue gas has passed through the first meter, the pen is made to drop to its initial position, from which it again starts to record. The maximum heights to which the pen rises are a direct indication of the percentage of CO_2 taken from the flue gases. The standard chart records from 0 to 25 per cent. of CO_2, and covers a

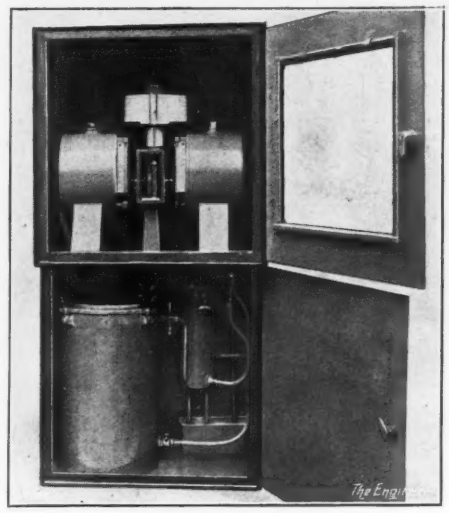


Fig. 4—C O_2 RECORDER

period of 24 hours. The instrument may be adjusted to make as many as 25 analyses per hour.

Another ingenious instrument which was shown, but which does not appeal so forcibly to engineers as those previously described, is a recording clinical thermometer of the thermo-electric type. It is a form of recording thermometer specially developed for medical research. The thermo-couple used consists of copper and constantan. This couple is connected to a very sensitive recording galvanometer, of the type known as the thread recorder, so that a record of the patient's temperature is obtained on a chart. The special feature of the instrument is the thermostat for maintaining the so-called "cold junction" of the thermo-couple at a constant temperature. It consists of a heat insulating vessel of the "Dewar" type, inside which are fixed two coils and a thermostatic relay. The latter, which is shown in Fig. 5, consists of two bimetallic strips—

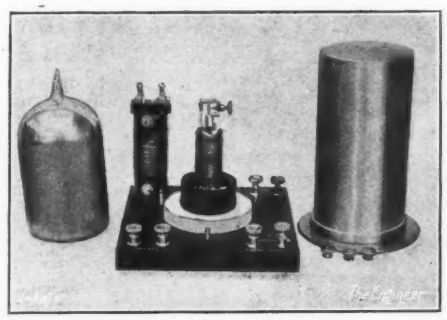


Fig. 5—THERMOSTAT

each of copper and invar—fixed at their lower ends, but with their upper ends free. A screw is attached to the upper end of one, and adjusted so as to come into contact with the other strip only when the temperature of the strips exceeds the required temperature, say, 35 deg. Cent. If the temperature inside the "Dewar" vessel is below 35 deg. Cent. a current is allowed to pass through the two heating coils, but as soon as the temperature reaches 35 deg. Cent. the movement of the strips relatively to each other is sufficient to cause the screw of the one strip to touch the other, with the result that one of the heating coils is short-circuited. The temperature inside the thermostat is thus maintained constant.

Muirhead and Co., Limited, of Elmers End, Beckenham, Kent, were showing an electro-magnetic rectifier, as illustrated in Fig. 6. This is claimed to rectify alternating current to continuous current in a simple, cheap, and practical manner. The principle will be understood from the diagram, Fig. 7. If the four contacts are connected up to the alternating-current mains F F and the arms of the switch S to a circuit requiring direct current—an accumulator, for instance—then if, for sake of argument, the

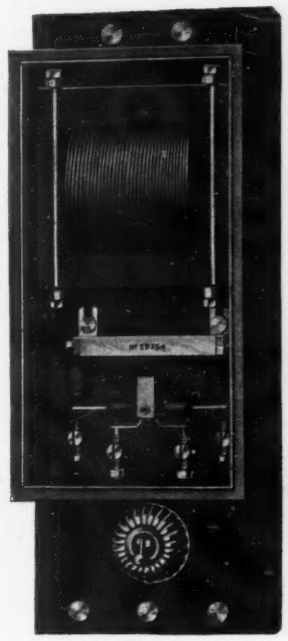


Fig. 6—RECTIFIER

current from the supply F F changes in direction once every minute and the switch is operated left or right once every minute, it is obvious that the accumulator will receive uni-directional current. In these rectifiers a switch

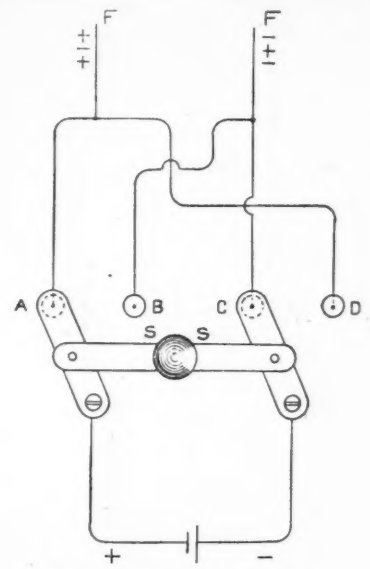


Fig. 7—DIAGRAM OF RECTIFIER

rapidly reverses the connections at the right moment, *i.e.*, when the current in the alternating-current mains is changing its direction. A diagram of connections for a rectifier with two contact points is shown in Fig. 8. This

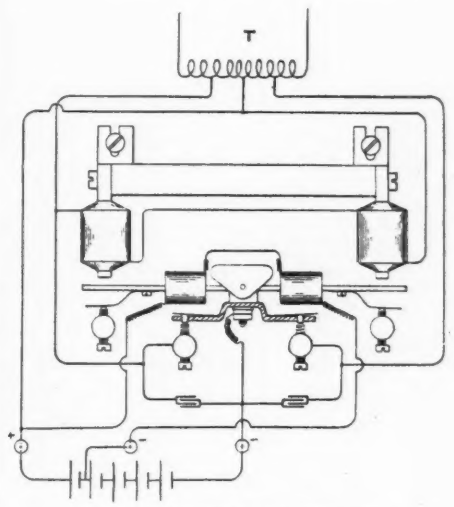


Fig. 8—CONNECTIONS OF RECTIFIER

is self-explanatory. It will be seen that the moving contacts are attached to a rocking lever pivoted in the centre, and that the lever is actuated by electro-magnets fed with

alternating current. The lever is magnetised with direct current, which, as can be seen from the diagram, is obtained from the battery. Rectifiers of this kind can be built with four contact points if it is required to rectify the alternating current with no change in pressure. In most cases, however, it is necessary to obtain direct current at a lower or higher pressure than that of the mains. To obtain this a transformer is used with two secondaries—as shown at T—and a neutral point forms one pole of the direct-current circuit. These two secondaries are automatically connected up alternatively and synchronously at each half-period and the circuit fed by these secondaries receives uni-directional current.

Morris and Lister, Limited, of Carlton Works, Lockhurst-lane, Coventry, were showing a new time element circuit breaker. This appliance, which is illustrated in Fig. 9, and which may be used on either direct or alternating-current circuits, depends for its action on the expansion of two strips of metal which carry the current

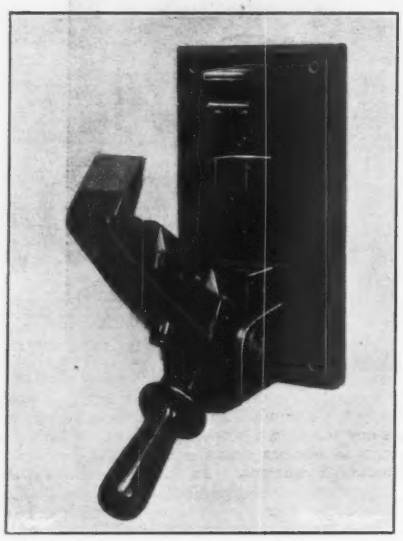


Fig. 9—CIRCUIT BREAKER

of the circuit to be protected. Owing to the thermal capacity of these heater strips, the delay in opening the circuit is greater with small overloads than with large. For motor work this means that a good protection is obtained, and better than is possible with circuit breakers which are magnetically operated, since these must be so set as not to trip with the large momentary current at starting. The breaker exhibited is a 150 ampère free handle pattern. From the time element curve shown in Fig. 10 it will be seen that a 100 ampère breaker would just operate at 125 ampères, and that a

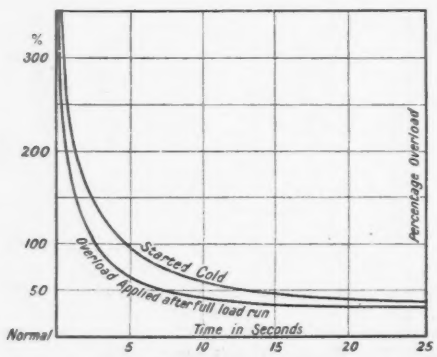


Fig. 10—TIME ELEMENT CURVE

100 per cent. overload would trip the breaker in 2½ seconds if the circuit had previously been operating at full load, and in 4½ seconds if the circuit had previously been without load. With 200 amperès, however, the action is very much quicker, taking ⅛ths of a second and 1½ seconds respectively for the conditions referred to. The carbon break and auxiliary contacts are also special features of the design. The free handle action is obtained in a very simple manner by mounting the locking catch upon a rocker, which is caught at the bottom by means of a spring catch. This spring catch enables the makers to supply no-voltage gear and other types of release, in addition to the overload action. If required the normal overload setting of the breaker can be adjusted up to the capacity of the next larger size by shunting the thermal strips.

Perhaps the most interesting piece of apparatus shown on the stand of H. Tinsley and Co., of Stanley House, Eldon Park, South Norwood, was Dr. Drysdale's alternating-current potentiometer. The various improvements which have been made in this instrument during the past year are embodied in the instrument which was exhibited. These lie principally in the sine flux phase-shifting transformer, which is now made to give a pure rotating field, so that when the instrument is in use and the phase angle is being balanced no adjustment for current is necessary, provided the frequency and voltage remain constant. For the benefit of our readers who are not familiar with the instrument, we may mention that it consists of a standard form of direct current potentiometer, to which is added a dynamometer for indicating the current in its coils. The phase-shifting transformer referred to is added in the right-hand bottom corner; by it the current can be brought into correct phase relation with the current that is being measured by simply turning a tangent screw. By means of a change-over switch the potentiometer may be either fed with direct current from a battery, and used with a galvanometer in the ordinary manner, or fed with alternating current from the phase-shifting transformer, and used with a vibration galvanometer or other alternate current detector. The instrument is designed for the rapid and accurate measurement of both alternating and continuous currents and voltages. Vector diagrams which have been drawn from its readings show a remarkably good result, even when measuring alternating currents in a condenser or in an inductive coil. That is to say, when these currents differ in phase by many degrees, either leading or lagging.

This alternating current potentiometer was shown in use with a Drysdale-Tinsley vibration galvanometer. The principle of this instrument will be understood from the illustration—Fig. 11. S P is the suspension piece carrying

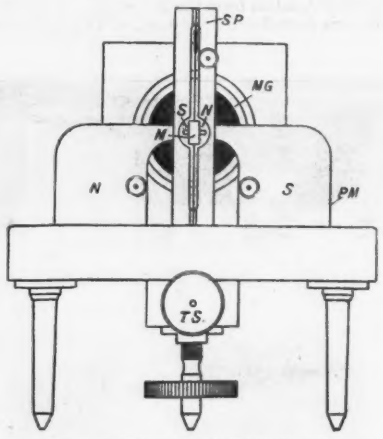


Fig. 11—VIBRATION GALVANOMETER

the moving system M C, the magnetising coil through which the alternating current flows to actuate the needle. P M is the permanent magnet, giving directive force to the moving system. A magnetic shunt is also provided which traverses the two links of the permanent magnet by turning the thumb screw T S. The motion of this magnetic shunt increases or decreases the amount of magnetism acting on the suspended needle, and forms a very ready and robust method of bringing it into resonance with the frequency of the alternating current being measured. The pole pieces N S are slightly adjustable in order further to diminish the controlling force. By this means the scale of the galvanometer can be opened out for different frequencies, and made to give as much as 2in. for a difference of timing of ten periods in the neighbourhood of 50 per second. This galvanometer, we are told, has been designed to meet the demand for a vibration galvanometer for use in connection with the alternating current potentiometer, and is specially suitable for use in circuits of ordinary frequency. It is said to be extremely useful in the measurement of inductances, capacities, &c., and as an instrument for the detection of minute periodic or alternating current or voltages. It can also be used as a sensitive frequency indicator, for when it has once been timed to a given frequency it will only respond to that frequency.

There was an excellent display of meteorological apparatus, sunshine recorders, rain gauges, recording barometers, thermometers, &c., on the stand of Negretti and Zambra, of 38, Holborn-viaduct. Perhaps from an engineer's standpoint the recording anemometers were of the greatest interest. Generally speaking, recording anemometers may be classed under two headings, *i.e.*, those based on the principles of the pressure tube and on the hemispherical cups. The latter is the principle adopted in Negretti and Zambra's electrical recording anemometer. The transmitting and recording instruments are connected by a simple three-wire cable, and the fitting up of the instrument presents no difficulty. In order that the curve on the chart may be gradual and free from steps, the transmitting mechanism is arranged to make ten contacts to the mile. It may appear that this would soon cause the batteries to run down, but the precaution against this is the subject of a patent under which the apparatus is constructed. The design makes provision for automatically reducing the period of the electrical transmission to a unit of time irrespective of the quickness or slowness with which contact is made. Under these conditions the battery power required is small.

The firm's electrical wind vane was also on view. The great difficulty which has to be overcome in electrically indicating the direction of the wind is the erratic manner in which the wind changes from point to point. It may continually shift in direction from one point to another in quick succession either backwards or forwards, or it may move slowly, or remain in one direction for long periods. In the instrument which was exhibited, however, provision is made for automatically reducing the period of the electrical transmission to a unit of time irrespective of the slowness or quickness of the movement of the vane, and the change of direction is denoted on the dial simultaneously as the vane points to any one of the eight cardinal points.

The firm of Elliott Brothers was exhibiting precision and commercial instruments of the portable and switchboard types, and suitable for continuous and alternating currents. The Wimperis accelerometer for traction and lift work was also on view. In addition there were micrometer gauges and miscellaneous instruments.

Many interesting exhibits were to be found on the stand of Everett, Edgcumbe and Co., Limited. The firm's pocket "Luxometer" was shown in use. This is for illumination and candle-power measurements, and may be employed either for daylight or artificial light. The instrument measures 7in. by 3½in. by 2in., and weighs less than 1 lb. It can also be provided with a Trotter daylight attachment, and is thus particularly suited to the requirements of borough surveyors, architects, health officers, and others. An improved form of the Trotter portable photometer was also on view.

An exhibit appealing to electric traction engineers was a trolley standard leakage indicator. This instrument has been introduced to comply with the Board of Trade recommendations as regards an indicator for showing when the trolley standard on a double-deck car becomes alive through the occurrence of a fault. In the past bells or coloured lamps have been employed, but have been found unsatisfactory. This new instrument consists of a self-contained fuse and high-voltage buzzer, which can be directly connected to the 500-volt system, and indicates unmistakably the occurrence of a fault. It is provided with a special testing arrangement whereby it can instantly be ascertained whether the instrument is in working order. Another exhibit appealing to traction engineers was a Trotter combined accelerometer and gradient measurer for the rapid determination of starting accelerations, comparison of various kinds of brakes, the measurement of tractive effort, the brake horse-power of a motor and tramcars, and the measurement of gradients. A number of other novel and interesting exhibits were shown by this firm.

On the stand of the India-rubber, Gutta-percha, and Telegraph Works Company, Limited, a new Silvertown Bleeck-Coke primary battery was shown. This is a new two-fluid cell, the special features of which are its high electromotive force, great current capacity, and constancy under varying loads. There was also one of Rymer-Jones's patented condensers. This is a new pattern of standard condenser, in which the usual separate elements are mounted in an air-tight glass cylinder. Two types of Silvertown portable testing sets were on view—one a combined testing set for measuring conductor resistance and insulation resistance for voltages up to 600. The other set was a small and cheap form of Wheatstone bridge with galvanometer. Lastly, there was a universal shunt of the Rymer-Jones pattern, with improved dials for facilitating the reading of the shunt values.

Some of the instruments shown by Robert W. Paul were dealt with in our articles on the last Machinery Exhibition held at Olympia. Among other things this firm was showing a uni-pivot universal set for direct-current measurements, from .0000002 ampères to 120 ampères, current shunts, a "Unipivot" milli-voltmeter, a new type of series resistance box, a portable Wheatstone bridge, unipivot alternating-current instruments, a Drysdale standard resistance coil, pyrometers, &c.

The firms exhibiting spark coils and accessories were Harry W. Cox and Co., Newton and Co., Leslie Miller, and Wright and Co. On the stand of Marconi's Wireless Telegraph Company there was an improved form of receiver for wireless telegraphy. The British Radio-Telegraph and Telephone Company, Limited, exhibited a multiple rotary spark gap employed in wireless telegraphy for preventing arcing by air currents and producing musical notes by interrupting the condenser discharge at regular intervals. Some up-to-date electrical instruments were shown by Crompton and Co., Limited, of Chelmsford. There were ammeters and voltmeters of the moving coil and moving iron types. Also a combined ammeter and voltmeter, a direct reading pyrometer with various thermo-couples, a D'Arsonval galvanometer and Wheatstone bridge, a Crompton potentiometer, and a 100 ampère standard resistance for use with the potentiometer.

Another firm exhibiting electrical instruments was Nalder Brothers and Thompson, Limited. On this firm's stand there was a portable standard ammeter, a portable standard voltmeter, testing sets, and other instruments. The Weston Electrical Instrument Company was also in evidence. On this stand there were switchboard and portable instruments of the permanent magnet moving coil type, portable testing sets for continuous-current work, switchboard instruments which can be used for both alternating and continuous currents, dynamometer-type watt meters and volt meters for alternating and continuous currents, and electric speed indicator and pocket volt meters.

Among other exhibits, on the stand of A. C. Corsor, Limited, there was one of Cooper's patented speed indicators. This is an instrument which can be used for very low as well as high speeds. The essential part of the indicator is a branched glass tube containing mercury which supports a column of liquid. A viscosity apparatus constituted one of the exhibits of Gambrell Brothers. This is for investigating the laws according to which the vibrations of a disc oscillating in a fluid are damped. The Foster Instrument Company exhibited a fixed focus radiation pyrometer and the Foster "Base Metal" thermo-couple. Many interesting pieces of scientific apparatus and electrical instruments were shown by the firm of W. G. Pye and Co. Among other things there was an example of the Aldis three-sphere sphereometer, galvanometers, potentiometers, volt-boxes, a Wheatstone bridge of the enclosed dial type, a Dolezalek electrometer, condensers, a new type of rheostat, &c. A novel apparatus, designed for detecting by means of conductivity the presence of, and the quantity of, extraneous matter dissolved in water and other liquids, was shown by Evershed and Vignols, Limited. The exhibits which we have referred to are those which appeal more particularly to engineers, and no attempt has been made to cover the complete field, but there were many other ingenious pieces of apparatus used in various scientific pursuits.

RAILWAY MATTERS.

ACCORDING to the *Contract Journal* the triennial programme of railway construction in India has been framed and awaits approval. The total expenditure for 1911–12 may amount to between £8,000,000 and £10,000,000 sterling, according to the money market.

WE hear that Berlin suburban authorities are still considering the advisability of applying the trackless trolley system to connect up some of the districts sadly in need of increased facilities for public traffic. Special commissioners have already studied the working of this system in the vicinity of Vienna, and are now proceeding to Bremen, where it appears to be giving satisfactory results.

AN important signalling apparatus was erected at the St. Margaret's works of the North British Railway, in Edinburgh, on December 13th. It is intended to obviate the danger of accidents to railway servants by being run down by passing trains. A box somewhat similar to that in the Waverley Station, which indicates at which platform a train will arrive, has been mounted in a conspicuous position, and the indicators show whether the up and down lines have trains on the section or not.

THE Schöneberg Electric Underground Railway was opened to public traffic on the 1st inst. According to the *Railway Gazette*, a five-minute service is provided during the greater part of the day, with a ten-minute service early in the morning and in the small hours. Steps have been taken to increase the capacity of the Elevated and Underground Railway, which interchanges traffic with the Schöneberg Line, and a 3½-minute service is being arranged for. The six-car trains recently introduced on the Elevated are being increased in number during the rush hours.

A NEW railway is projected from Grassington through Coverdale, Middleham, and Spennithorne to Scorton, there joining the North-Eastern Railway. The total distance will be 33½ miles, and will open out a district rich in agriculture and minerals. From Grassington the line will run up Wharfedale nearly to Kettlewell. The most difficult piece of work will be at East Scale Park, where a tunnel 4800 yards long will have to be made. The gradients and curves will be such as to permit the running of very fast trains. The railway will cross the Yore by a viaduct about 50ft. high.

OPERATION of trains and public use of the whole of the new Pennsylvania station, New York, began, says the *Iron Age*, at two minutes past midnight of Saturday, November 26th. The full schedule of trains at present consists of 61 trains westbound and 55 trains eastbound every 24 hours. These do not include the 88 eastbound and 85 westbound trains of the Long Island Railway. Work on the tunnels was begun June 10th, 1903, and the station was begun May 1st, 1904, so that more than seven years have been consumed in construction. Preliminary surveys and soundings were made for two years previously.

How largely the railway service in France is recruited from the agricultural classes—who, as in that country, find that employment far superior to work on the land—is clear from a statement made in the French Chamber of Deputies, reported by the Paris correspondent of the *Morning Post*, by the Republican Deputy, M. Emmanuel Brousse, who said: "I have been struck by the fact that on a railway line which has just been opened in my district 90 per cent. of the agricultural workers have applied for employment. If the postmen had not been reinstated *en masse* there would have been no railway strike. To repeat this blunder would be an act of cowardice which would disorganise the public services and ruin the country."

AT a meeting of the Buenos Aires Midland Railway Company, Mr. Frank Henderson gave an encouraging account of the work of construction and equipment, and read a cable received on the day of the meeting:—"Large tracts of land on both sides of line under cultivation, wheat, oats, linseed and maize having been sown extensively, and for first 300 kiloms. from Buenos Aires present prospect of good harvest is promising; from kilom. 300 outwards harvest prospects not so good, in consequence of drought, and towards Carhue damage has been considerable. Recent rain, however, throughout Buenos Aires Midland Railway zone has been beneficial. Passenger traffic and outwards goods traffic increasing, and we expect good traffic in live stock. It is proposed to open whole line to public traffic on 1st January next year."

THE Russian Government have granted a concession for the proposed Kakhetian Railway in the Caucasus. It is stated in the *Railway Times* that the corporation of noblemen of the Government of Tiflis, who are promoting this railway scheme, have already received a number of offers for their concession from various foreign syndicates, in view of which the scheme promises to be realised in a very short time. The proposed railway line will extend from the Navtlug Station on the Transcaucasian Railway to the town of Telava in the Government of Tiflis. Thus it will link the province of Kakhetia, one of the richest districts, and the wine-growing centre of the Caucasus, with Tiflis, the heart and administrative centre of the country. The total length of the new railway line will be 174 versts—about 120 miles.

TIMBER for railway sleepers in Brazil, states the *Railway News*, is still shipped from Bahia and other States, and timber is exported from the pine forests of Parana through the ports of Antonina and Paranagua, and in small quantities by rail to the San Paulo market. Exports of the more expensive cabinet woods fell off in 1909. The Brazil Railway Company, which controls a vast network of railways connecting San Paulo, Parana, Santa Catharina, and Rio Grande do Sul, possesses a huge forest domain, acquired partly by purchase, partly by concession of the Federal Government, for the construction and working of the San Paulo-Rio Grande Railway. This domain, situated along the railway lines, has an area of 6,000,000 acres. The tracts of forest are being measured for purposes of exploitation, and consist of pine and other hard woods. According to the report of North American experts, their wealth alone would justify the construction of a railway to the port of San Francisco, and their development should curtail the imports to Brazil of pine wood from the United States, which in 1909 amounted to 74,000 tons.

ACCORDING to the *Electrical Review* no objection is to be raised by the Borough Council to a proposal for the construction of additional junction lines between the London County Council tramways in Queen-street, Hammersmith, and the London United Tramways in Beadon-road and King-street. It was mentioned in a letter from the London County Council that negotiations are at present proceeding with the London United Tramways for the purchase of the portion in London of the company's undertaking, and the new junctions will not be constructed until after the purchase is completed. Last month the Borough Council wrote to the Board of Trade renewing the application for the nomination of a referee to determine the difference which has arisen between the Council and the London United Tramways (1901), Limited, with regard to the condition of the tramway tracks. The Board has now written to the Council enclosing a copy of a communication received from the company, intimating its intention to keep the tramway tracks in a proper state of repair. The town clerk was directed to reply to the Board of Trade, pointing out that during the last three years notices had been served from time to time upon the company, in which the specific requirements of the Council with regard to the repair of the tramway tracks had been set out; that the tracks and rails are in a defective and dangerous condition generally, and that the only effective and satisfactory way of dealing therewith is to reconstruct and relay the paving throughout the whole length of the tracks in respect to which representations had been made by the Council.

NOTES AND MEMORANDA.

SHEET aluminium, states the *American Machinist*, makes better vice jaws than either copper or brass. It can be obtained in any thickness from machinists' supply houses.

BLASTING at Panama during August, September, and October required, on the Central Division, 543.58 long tons of dynamite for 3,369,064 cubic yards of rock excavated. For these months in 1909, 3,347,301 cubic yards of rock required 953.30 long tons of dynamite.

THE consumption of nitrate of soda in the world for the first eight months of 1910 amounted to 2,125,232 tons, against 1,718,270 tons for 1909. This breaks the record, according to consular reports. The increase in August amounted to 13 per cent. over the same month for last year.

AMONG the many curious investigations carried out by means of instantaneous photography, not the least interesting are those which Professor Worthington has devoted to the study of the effects produced by the fall of drops or solid spheres into water or other fluid. These investigations will be described and illustrated in this year's Christmas lectures at the Royal Society of Arts by Professor Worthington.

STATISTICAL investigations made with a view to ascertaining the state of the German machinery industry during 1909 include the work of 259 limited companies, with a total nominal share capital of 585.6 million marks, and it was found that whilst a few firms had increased their trade and made better profits than in 1908, the year 1909 was unsatisfactory for the industry as a whole. The number of firms paying no dividends has increased, and, where dividends have been declared, they are in almost all cases on a lower scale than in the preceding year.

A PAPER entitled "Recent Developments in Condensing Plants" was read recently by Mr. G. L. Kothny, before the Junior Institution of Engineers. The paper was devoted to the various forms of condensing plant which have been designed to take advantage of the high degree of vacuum obtainable by the use of the Leblanc rotary dry air pump. A number of tests of such plant were given, including some of the multiple-jet Leblanc condensers at the Neasden power-house of the Metropolitan Railway and the London County Council power station, Greenwich.

CONSIDERABLE progress has been made in the nitrate industry in Chile during the current year. The production of nitrates for the first nine months was 3,942,648 tons, as against 3,200,039 tons in the corresponding months of last year; while the quantities exported during these periods were respectively 3,092,506 tons and 2,847,564 tons. It is reported that several of the works are now controlled from the United States, and that negotiations are in progress for the acquisition of others. The outlook for the industry is considered to be promising, even at the present prices for nitrates.

STATISTICS supplied by Mr. Langlands, superintendent of gas lighting to the Glasgow Corporation, with regard to the use of incandescent gas mantles in the lighting of the streets of the city were given in a recent lecture given by Mr. Frederick Soddy, F.R.S., on "Thorium: Its History, Uses, and Radio-activity." The number of mantles used per annum in Glasgow is 200,000. About 9½ mantles are used per gas lamp in the Glasgow streets every year, and the quantity of gas consumed per mantle averages 1000 cubic feet. About 1 cwt. of ash is recovered each year from the mantles used in the lighting of the city streets, and is returned to the manufacturers to be utilised in the making of new mantles.

IN an article in the November issue of the "Yale Scientific Monthly," the general superintendent of motive power of the Pennsylvania Railway states that there is no doubt that the tungsten lamp will replace the carbon lamp for train-lighting work. The success attending its use may be attributed to the development of the so-called "hot circuit." By means of this method, instead of turning the current completely off from the lamps when light is not required, the lamps are merely disconnected from the main batteries and joined to one or two "hot circuit" cells, sufficient current being thus passed through the lamps to show merely a faint red at night. This arrangement minimises the breakages of the filament.

ELECTRIC lights for drawing boards in an office where the work requires very long drawings, states the *Engineering Record*, are suspended from wires strung below the ceiling parallel with and directly over the boards. The connections are taken from convenient ceiling outlets and the lamp cords are permanently tied to small white porcelain spool insulators. These insulators are strung on the wires by passing the latter through the nail hole. Sufficient cord hangs from the insulator to allow the lights to be dropped quite close to the boards, and enough slack is left between the insulator and outlet plug so that the lights can be moved a considerable distance along the wire, and thus be placed directly over the desired point without moving the drawing. This is particularly advantageous in studying completed drawings.

CLOSE JOINTED granite block pavement was experimented with at Boston, Mass., during 1909, and in the last annual report of the Street Department of that city. Mr. Guy C. Emerson, at that time superintendent, expresses the hope that this method of construction may be adopted as a standard for the future. Since the general use of concrete as a base it has seemed to him that the conventional block in Boston, with its depth of 8in., contained an excessive amount of granite and the depth rendered it impracticable to prepare the vertical faces in such a manner as to lay with a close joint. A block of approximately 5in. depth, with the same wearing surface, has been laid to cover 12,000 square yards on Massachusetts-avenue with a maximum joint of ⅛in. This, Mr. Emerson states, has given a very satisfactory pavement, of greater smoothness than the previous standard. It is anticipated that the close joints will obviate the rounded corners now so common and also prevent to a great extent the noise from granite blocks. It is also believed that a softer quality of granite may be used than formerly, offering a more gritty surface and better foothold for horses than the hard granite.

ACCORDING to a note in the *Electrical Review*, the total available horse-power of the rivers of Canada is stated to be 25,682,907 on the basis of minimum flow development. Of this total only about 2 per cent.—516,887 horse-power—is now developed. The distribution of the water-powers in the various provinces is as follows, the figures representing horse-power:—Yukon, 470,000; British Columbia, 2,065,500; Alberta, 1,144,000; Saskatchewan, 500,000; Manitoba, 504,000; North-West Territories, 600,000; Ontario, 3,129,168; Quebec, 17,075,939; New Brunswick, 150,000; Nova Scotia, 54,300. In January there will be submitted to the Dominion Parliament a Bill respecting the water-powers of Canada. The objects of the law came under seven heads as follows:—(*a*) Water powers to be alienated for stated periods only. (*b*) Reference of the application for water powers is to be made to the Conservation Commission before alienation. (*c*) Determination of the development to be made, and the right of entry and the annual rental calculated on the horse-power used. (*d*) Time within which proposed development is to be made, and forfeiture in case of non-observance, and revision of rentals at expiry of each period. (*e*) Indemnification of lessee in case of failure to agree after each period. (*f*) Control of rates at which the public at large is to be supplied with electric power by the lessee. (*g*) Jurisdiction to determine differences between the Government and lessees in case of failure to agree in some independent tribunal.

MISCELLANEA.

MADRAS, states a contemporary, is agitating for a series of wharves so that ships may load and discharge directly, instead of by the cumbrous method of from ship to lighter and from lighter to shore, and *vice versâ*.

THE work in connection with the restoration of the ancient oak roof of Westminster Hall, which has been in progress since the House adjourned in August, has now been suspended for the time, and the huge scaffolds are being removed. The work will be resumed when Parliament again adjourns.

THE importation of acetic acid into Servia has been prohibited on the recommendation of the Board of Health. Shipments of acetic acid already *en route* for Servia will not be allowed to enter the country unless diluted, under strict supervision of the custom-house officers, to the strength of table vinegar.

ACCORDING to a contemporary, aviators are beginning to complain that cross-country wires carrying currents of extremely high voltage are a source of great danger to aeroplanes. The French aviators agree with their German *confrères* in this. They agree with the suggestion that the masts should be painted a brilliant red so that they can be seen from a good distance.

IT is reported in the *Contract Journal* that New Zealand has in hand a huge scheme to supply electric power for all kinds of purposes from her great lakes and rivers—power for factories and railways, and also for lighting purposes. It is proposed to establish several centres, and to spend £2,000,000 in money and four years in time to accomplish the work. Under the scheme the Dominion will be divided into seven districts, and each will possess a generating plant.

AT the meeting of the Illuminating Engineering Society, Dr. Silvanus P. Thompson, F.R.S., the president, stated that the council of the Society had decided to appoint a committee of its own members, with power to consult with others, to draw up in a preliminary form a model specification for street lighting. Their idea was to produce something which would serve, irrespective of any particular form of illumination, to show borough surveyors and architects the proper way to specify how streets should be lit.

THE plans and specifications of the Admiralty's new explosives works at Crombie, in the neighbourhood of the Rosyth navel base, are practically completed. Most of the inland works will be constructed to the east of Kinninnie Point, thus leaving a large tract of land to the west of the point for future development. The works, exclusive of the branch railway line, will cost well over £100,000. The contract for the construction of the branch railway line is also under consideration. The intention is that operations on both the explosives works and the branch line shall commence early in the spring.

AT the commencement of the new year Germany will have a fairly complete system of telegraphy between herself and her colonies. An installation has been built which will enable communication to be made with German East Africa. As noted recently in these columns a very successful service of communication exists between Germany and German West Africa. An installation is to be erected in German Oceania so that East Africa, West Africa, and the German Islands in the Pacific will form the base of a vast triangle with invisible sides, having Prussia as its apex. The whole present and future cost of installation comes to about 10 million marks, the cost of a very small warship.

A SUCTION dredger record for New York State barge canal work was made in October by the dredge Champion, working on the Champlain Canal. The dredger has a 20in. suction and a 20in. discharge pipe, and during the month was working in excavation much easier than the average. The total yardage removed was 500,352, and, deducting the excavation below grade, the net quantity to be paid for was 470,352 cubic yards. The actual working time was 565 hours and 35 minutes, giving an average per working hour of 885 cubic yards. The former dredging record on the barge canal was made in September, 1909, in the Montezuma marshes, when a single machine took out 454,706 cubic yards. The Champlain belongs to the Atlantic, Gulf and Pacific Company, New York.

THE percentage of aeroplane accidents in relation to the number of aviators and the mileage covered by them has been proved by M. Soreau to be considerably less than is generally assumed to be the case. Lecturing before a meeting of French civil engineers, M. Soreau stated that up to November 4th the Aviation Committee of the Aero Club of France had delivered 271 flying licences. Taking all countries, the number of pilots and pupils was about 500, and the percentage of persons killed was six. "But," added M. Soreau, "in order to estimate the risks we must also take into account the distances covered, which may be set down at an aggregate of 125,000 miles for all the aeroplanes in the world. This gives us one fatal accident for every 4375 miles, and it must be borne in mind that this includes aeroplanes, which frequently hitherto have been nothing but experimental machines, and that aeroplanes are not yet perfect." In M. Soreau's opinion the most important problem in dealing with the transformation of the sporting aeroplane into a transport aeroplane is the solution of the question of the landing of fast machines.

THE Russian Minister of Trade and Industry is, according to the *Ironmonger*, submitting proposals for stopping the export of raw platinum from Russia. This metal, of which the world's consumption is about 6½ tons a year, is obtained almost exclusively from Russia, and up to the present has been exported in a crude state—with the exception of about 2 per cent.—the purchase being confined to one house abroad, which, as monopolist, controls the market. This condition of affairs, and the desirability of developing the home manufacture of the metal, have prompted the Minister to take action. The proposals are as follows:—(1) The eventual prohibition of the export of raw platinum; (2) the erection of a State factory to refine the metal, should private enterprise be unable to cope with it; (3) the making of advances by the Imperial Bank on platinum, and also for working expenses; (4) the institution of regulations to govern the sale, purchase, production, and distribution of the metal; and (5) the enacting of penalties for any breach of the regulations. It is reported that a French company has expressed its desire to establish a platinum works in Russia in accordance with the proposed scheme.

ADDRESSING the members of the Birmingham and Provincial Gunmakers' Association at the annual meeting, Mr. A. A. Bonehill (chairman) congratulated the trade upon the fact that there had been sufficient work to keep them occupied all through the year. He was inclined to believe that the volume of business had been far in excess of that in previous years. Referring to the Gun Trade Technical School, he said that remarkable progress had been made. Pupils received instruction in all stages of gun manufacture. If the school continued to receive the support necessary to ensure its success, the municipal authorities would next year take over the complete control. He appealed to members of the trade to give the school practical support, and mentioned that while the Birmingham School had only 47 pupils, at Liège there was a school with 247. An important matter which had been before the Gun Trade Section of the Birmingham Chamber of Commerce had reference to English-made guns sent from America to England for repairs. On their being returned to America, after being repaired, duty was again charged upon the full value of the guns. Negotiations had been proceeding between the Birmingham Chamber of Commerce and the New York Chamber, and he hoped that the existing serious obstacle to business would be removed.

THE WORKS OF JOHN COCKERILL, SERAING, BELGIUM.

In the year 1800, a young Yorkshireman named John Cockerill emigrated to Belgium. He prospered as an engineer, and in 1817 set up a small ironworks on the banks of the Meuse. This enterprise has now developed into the Société John Cockerill, employing 11,000 workmen, with a capital of £500,000, and paying a dividend of 18 per cent. The company is managed by a council of which Baron Fernand de Macar is president, and the works are under the able direction of M. Adolphe Greiner. The artillery department is in charge of Mr. E. Ternström, formerly of Nordenfeldts, and Major De Schryver.

The men work fifty-nine hours a week. The wages

Fig. 1—BIRD'S-EYE VIEW OF THE WORKS

paid are about 2s. 6d. a day for labourers, 3s. 4d. for machine minders, and 4s. for men tending machines of precision. Generally speaking, the wages are from 30 to 40 per cent. below British scale. On the other hand, the cost of lodging and provisions (with the exception of butchers' meat) is less than in England. The men usually get one meat meal, of pork or bacon, a day. No female labour is employed in the district. Seventy per cent. of the workmen belong to the State Pensions Association, to which they pay an average annual contribution of 15s., an equal amount being contributed by the firm. This secures the man a pension of eightpence a day at the age of sixty.

The works, a bird's-eye view of which is given in Fig. 1, are situated near Liége, fronting the river Meuse on one side and the railway on the other. They extend over 360 acres of ground. They are in the centre of the Belgian coal district, and there is a coal mine on the works. The consumption of coal amounts to 350,000 tons per annum, of which 250,000 tons are supplied by the mine on the works, the remainder being obtained from neighbouring collieries or from Germany, at an average price of 12s. per ton delivered at the works. From 50,000 to 60,000 tons of coke are also purchased. The company is preparing to open a new coal mine at Genck, in the Campine, near Antwerp. It owns a mine in Spain producing high-grade hematite, but most of the ore is derived from the Meurthe and Moselle basins in France. It is an oolitic ore, known locally as "minette," and costs about 6f. per ton at the works. The annual consumption of ore is from 500,000 to 600,000 tons.

Except in the rolling mills, all the power used in the works is derived from blast-furnace and coke oven gas. The gas is taken off at the top of the blast furnaces, and passes downwards through a 30ft. dust-catcher; thence it goes to a 10ft. fan-washer, and to a Theisen rotary washer, of which there is one to each engine. The gas reaches the engine in a fairly clean state, and little trouble from grit is experienced. The power-house—see Fig. 7, page 672 - contains eight double-acting tandem gas engines, each of 1500 horse-power, working usually up to 1200 horse-power. Each of these drives a shunt-wound dynamo of about 1200 kilowatts. The 550-volt current thus produced is distributed through the works, electric driving being used throughout.

The steel works turn out about a quarter of a million tons of steel every year. They consist of a basic Bessemer plant, basic Siemens-Martin plant, and a Girod electric plant—see Fig. 6—for making special steels.

The Bessemer plant consists of a battery of five 15 ton converters lined with dolomite obtained in the neighbourhood. This is calcined, mixed with fried tar, and rammed by hand or with compressed air rammers. The body lining stands on the average about 180 charges, that of the bottom plug 40 to 45. The converters are charged with phosphoric pig from the blast furnaces; when below 2 per cent. of phosphorus phosphoric slag is added in the blast furnace. After blowing the metal is teemed into 2-ton ingot moulds on trucks. As soon as the moulds are stripped the ingots are lowered into a soaking pit, where they remain from twenty-five to thirty-five minutes till of the same temperature all through. They then go to the blooming mill. This comprises a set of reversible rolls, with positively driven reversible roller feed, the whole driven by an engine of 1800 horse-power. There is a set of fingers which turn the bloom through 90 deg. after each passage, and shift it laterally for the next passage. After passing five times through the rolls the bloom goes to the cropping shears. This is a fine machine by Breuer and Schumacher, of Düsseldorf, capable of shearing up to a cross-section of 625 square centimetres. This high power is obtained by the use of an intensifier. There is a larger shears for cutting blooms up to 35 cm. by 35 cm. adjoining the blooming mill. The bloom is cropped and cut into 8ft. lengths, which are reheated before going to the rolling mills; this re heating is necessary in order to enable the rails and plates to pass the high tests imposed by European customers.

An important economic feature of the basic process is the value of the phosphoric slag, which is broken in a machine resembling a coffee-mill and sold for manure, realising about 45f. per ton on a percentage of 16 to 18 of phosphoric acid. The blast furnace slag, which is nearly white, is sold for cement. The basic Siemens-Martin plant consists of three furnaces, each capable of casting a 15-ton ingot, so that a 45-ton ingot can be turned out. The charge consists of 25 per cent. of pig and 75 per cent. scrap, all from the works. Ferro-manganese is added in the bath, and ferro-aluminium—when used—in the ladle. This plant turns out nickel gun steel of high quality, and mild steel for boiler plates. The steel is remarkably low in phosphorus, and in the mild steel it is reduced to a mere trace. Bituminous coal from Germany has to be used in the gas producers, as the Seraing coal cakes too much. The consumption is 5.6 cwt. of coal per ton of steel.

The Girod electric plant consists at present of a single furnace—see Fig. 6—but more are to be added. The

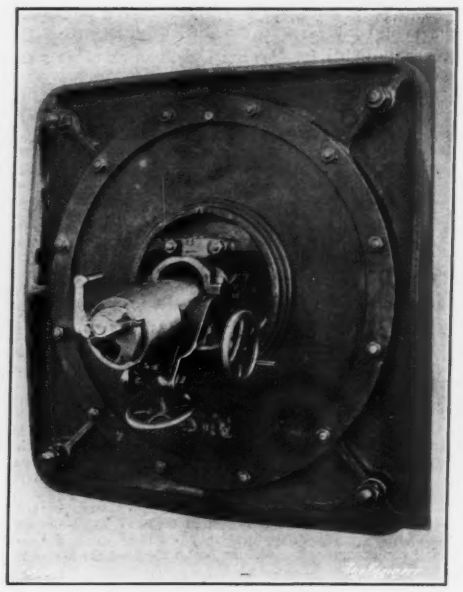


Fig. 2—PORTLESS CAPONIER GUN

converter, which takes a 3¼-ton charge, is cylindrical, lined with dolomite bricks, and has a water-cooled cover lined with fire-clay. It is charged from a ladle with steel from the Bessemer converter. The top electrode is then inserted; this consists of a carbon cylinder 9in. in diameter coated with ½in. of asbestos and water-glass. There are four iron water-cooled electrodes in the bottom of the converter. The carbon electrode is kept just clear of the slag, which is poured off as required by tilting the converter, and a current of 5000 ampères at 50 volts is passed through. The current heats the metal, but the bath remains very quiet. The phosphorus is immediately burnt out, and with it some of the carbon. The bath is re-carburised by pouring off the slag and strewing powdered coke on the surface of the metal. Lime is then added to remove the sulphur, and ferro-manganese to deoxidise the bath. The great point to be attended to is to keep the slag white and free from metallic oxide; this is effected by de-oxidising the slag with powdered coke. Tool steel and all kinds of special steel are made in this converter; the product is of very high grade, perfectly free from oxides, and therefore sound and without blow-holes.

The rail mill—see Fig. 3—has a capacity of 3000 tons per week, and the usual output is 110,000 tons of 105 lb. rails annually. The rolls are all of the reversing pattern, and are driven by a fine engine of 10,000 horse-power, made at the works—see Fig. 6, page 672. This engine has three pairs of cylinders, high pressure and low pressure coupled tandem, with link motion reversing gear; the steam pressure is 120 lb. per sq. in. The feed rollers and gear for shifting the rail from one pair of rolls to the next are all driven by electricity. For heavy rails it is not usual to roll more than three lengths from an ingot, but medium sections, 60 lb. to 75 lb., can be rolled in six or seven lengths.

The plate mills include a set of roughing rolls driven by a reversing engine of 1200 horse-power, a thin plate mill, and a universal mill rolling faces and edges. The two latter are three-high mills with lifting tables, both driven by a 1500 horse-power engine. There is also a very neat electrically-driven mill for angle irons, small rails, and rod iron.

The locomotive shops are capable of turning out two locomotives a week, the average number being one hundred a year, besides small engines. The company has no special pattern, but most of the engines turned out are of the four-cylinder compound type, having six coupled wheels and a bogie, and fitted with Walschaerts' valve gear and superheaters. These weigh up to 80 tons. Besides the Belgian State Railway, engines are supplied to France, Spain, Portugal, China and the Argentine; six are now in hand for the latter country. The company makes a specialty of small works' locomotives with upright boilers; these are remarkably handy little engines, and there is a steady demand for them. The locomotive shop is well equipped, and has a 40-ton crane and a fine frame-slotting machine made in the works. This takes eight 40ft. frames at a time; it has three tool-carriers, and its action is very rapid.

The engineering shops had at the time of a recent visit by our representative a great variety of orders in hand, amounting in value to £800,000 sterling. Among the principal items are twenty-six gas engines for blast furnace gas of 1500 to 2000 horse-power, several iron bridges, and three hydraulic lifts for the Canal du Centre, each capable of lifting a tank with a 400-ton lighter to a height of 60ft.; also the turbine engines for two Channel steamers, which are being built in the shipyard at Antwerp.

The gun factory is turning out 6in., 3in., and smaller guns for the Antwerp defences. A few old 11.2in. guns are being converted to howitzers, but guns of a large calibre are not made. The Krupp pattern field guns for the Belgian army were made in this factory. All the Cockerill guns have the Nordenfeldt eccentric screw breech mechanism, and are rifled with increasing twist. A competition for the selection of a field howitzer for the Belgian artillery recently took place; the Cockerill howitzer, which is reported to have done very well, has a combination of rear trunnions and recoil controlled by valves in the trunnions. The company used formerly to turn out tension gun springs, but there are fashions in gun making as in other trades, and these have never come into favour, although they have many advantages. One peculiarity of the tension spring is that it is in a state of initial compression when made, and that after firing for the first time it elongates, taking a slight permanent set; thereafter its behaviour is irreproachable, and it is impossible to break it. Messrs. Cockerill were turning out large numbers of their portless mountings for fortress defence—see Fig. 2. The cradle in this weapon is on a ball-and-socket joint in the armour shield, and there is a separate aperture for the sighting telescope. In the smaller calibres the gun does not recoil, but the ball-and-socket joint is in the centre of a disc 4ft. in diameter, made of 3.10 mm. thicknesses of spring steel, which gives slightly on discharge.

The company had also an order from the Congo Government for light guns suitable for carrier transport. The gun is not quick-firing, but is a 47 mm. breech-loading gun of very simple construction, making loads of 66 lb., except the gun load, which amounts to 132 lb., and is carried by two men. The Congo Government have bought up a number of the old Italian 7 cm. bronze field and mountain guns.

The armour plate work in hand consisted of single and double cupolas for 6in. and smaller guns. These are of forged steel, containing nickel and chromium, water-hardened at a low red heat (700 to 800 Cent.), and tempered. They are not face-hardened. The cupola dome is 9in. thick, double-lined with 0.8in. soft steel plates. For double turrets the domes are in three pieces, tenoned together. The dome plates are rolled and forged flat, then turned on a vertical lathe so as to be thickest in the centre, and then heated and pressed to shape. They are then of equal thickness throughout. Each cupola is mounted on a roller ring protected by a thick apron of mild cast steel, and is rotated by electric gear.

The particular feature of the Cockerill turrets—see Fig. 5—consists in the armoured dome being carried by a bearing ring of cast steel, on which it rests by a vertical tenon with lead cushions interposed. The object of the lead cushions is to allow for distortion, so that a shot striking near the edge of the armoured dome should not cause the cupola to jam. The bolts holding the dome down to the cast steel ring—which is supported directly by the rollers—bear on to spring washers, and can give to a considerable extent without allowing the dome to spring from the bearing ring.

The ammunition factory turns out field shrapnel and 6in. semi-armour-piercing shell and shrapnel. A few howitzer shell of larger calibre are also made. The capacity of the factory is 400 shell per day, but 800 can

THE COCKERILL WORKS

Fig. 3—RAIL ROLLING MILL

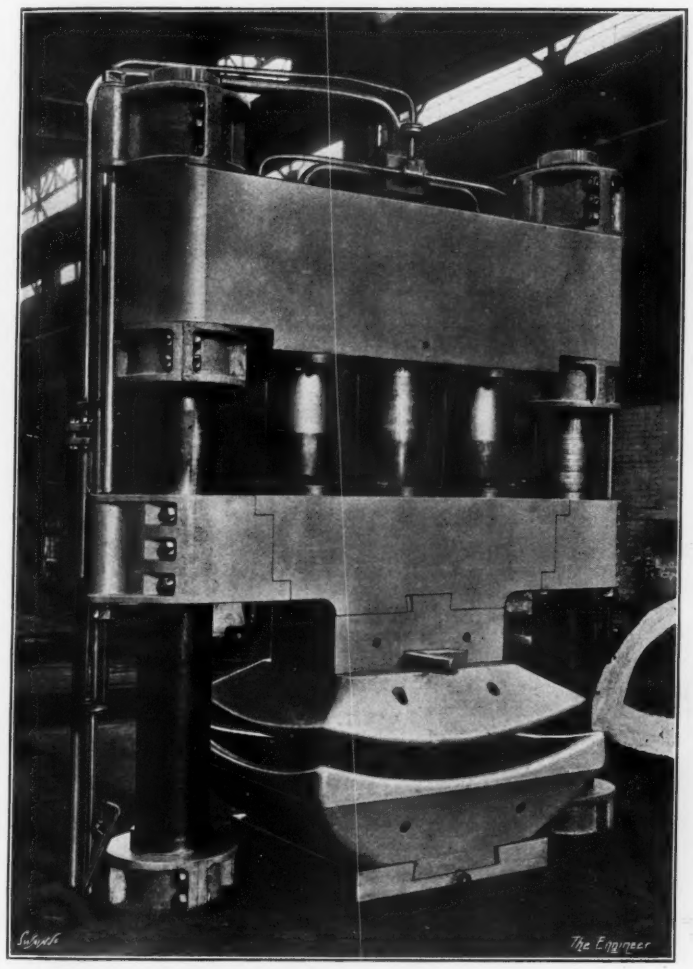


Fig. 4—2000-TON ARMOUR-PLATE PRESS

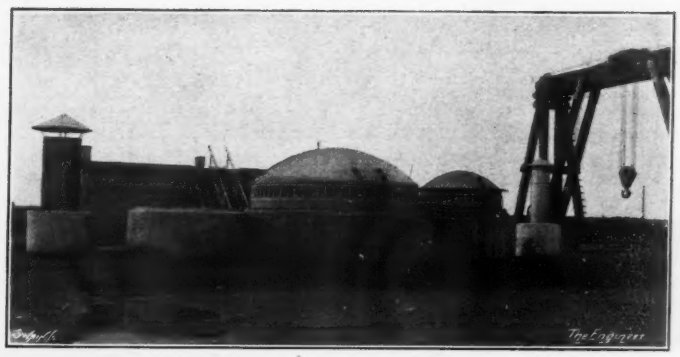


Fig. 5—GUN CUPOLAS AT THE PROVING GROUND

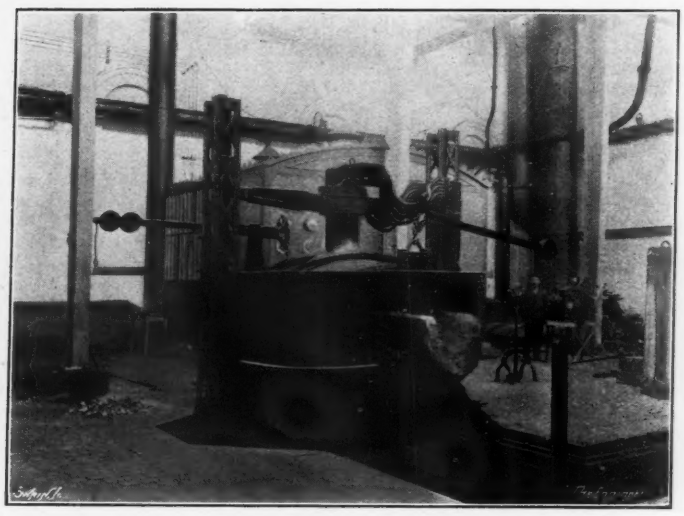


Fig. 6—3½-TON GIROD ELECTRIC FURNACE

be turned out on emergency. Shrapnel bodies are made of steel, containing 0.5 per cent. nickel; the tenacity after oil-hardening and tempering is 80 k/cm., yield point 52 k/cm., and extension 8 per cent. The armour-piercing shell are of nickel-chrome steel, with heads ground to a 3¼ calibre radius; caps are not used. Shrapnel bodies are pressed from the ingot, but not drawn; they are turned inside and out. The cartridge cases are obtained from Kynoch's. The machinery in the ammunition factory was made by the Progrés Industriel Company of Brussels, and seems well adapted to its purpose.

The vertical lathes used for turning cupolas and roller rings are fine pieces of machinery, having face plates 33ft. and 22ft. in diameter. These are on central pivots, the outer circumference of the face plate being supported on rollers. Great care has been taken to get them absolutely true, and the 33ft. lathe turns out work accurate within .002 in. Each lathe has two external and one internal tool-posts. There is a fine 2000-ton press for shaping armour plate—see Fig. 4. The ordinary method of cutting armour plates by boring holes close together is not used at Seraing, since no face-hardened plates are made. Plates up to 12in. are cut through with the oxy-hydrogen jet, and the adjacent metal planed off. Tools are mostly made of Armstrong's "AW" brand high-speed steel, and milling cutters are made of "Novo" steel, supplied by Jonas and Colver, of Sheffield.

Messrs. Cockerill have a small shipyard at Antwerp, employing 1000 men. They turn out paddle steamers up to 1500 tons for the Volga, and stern-wheelers of 400 to 500 tons for the Congo, and recently for the Euphrates.

One of the best-known vessels built by the firm is the turbine cross-Channel steamer Princess Elisabeth, which has for some five years now been plying between Ostend and Dover. She is a remarkably fast and steady boat, and makes the passage of over sixty miles in three hours or so. Latterly two further turbine boats of the same class—the Jan Breydel and the Pieter de Connick—have been built by Messrs. Cockerill for the same service. These vessels were boilered by Howdens, and ran their trials on the Clyde. The first named attained the high speed of 24.9 knots on the measured mile.

THE WORKS OF JOHN COCKERILL AT SERAING

(For description see page 670)

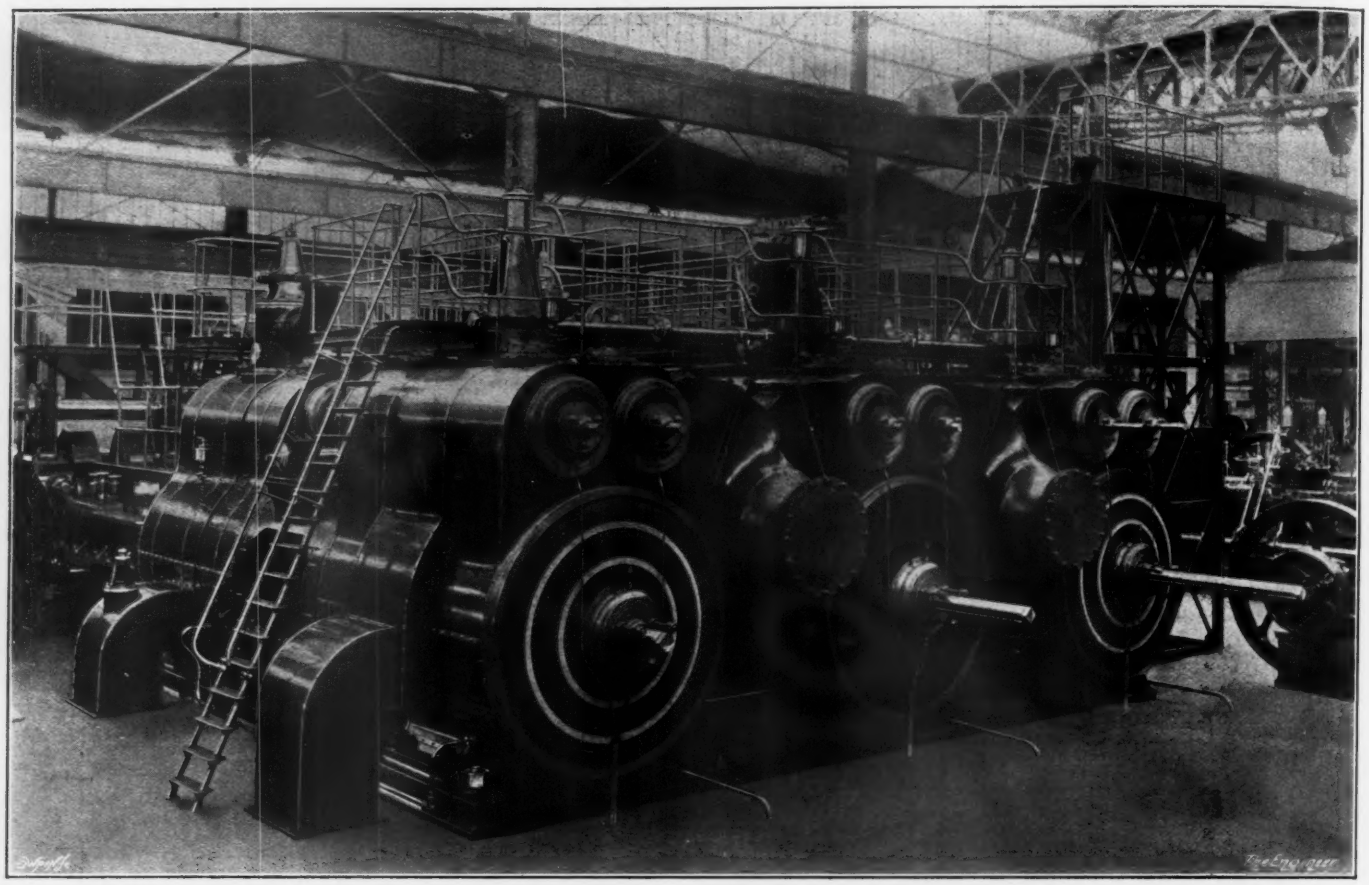


Fig. 6—10,000-HORSE-POWER ROLLING MILL ENGINE

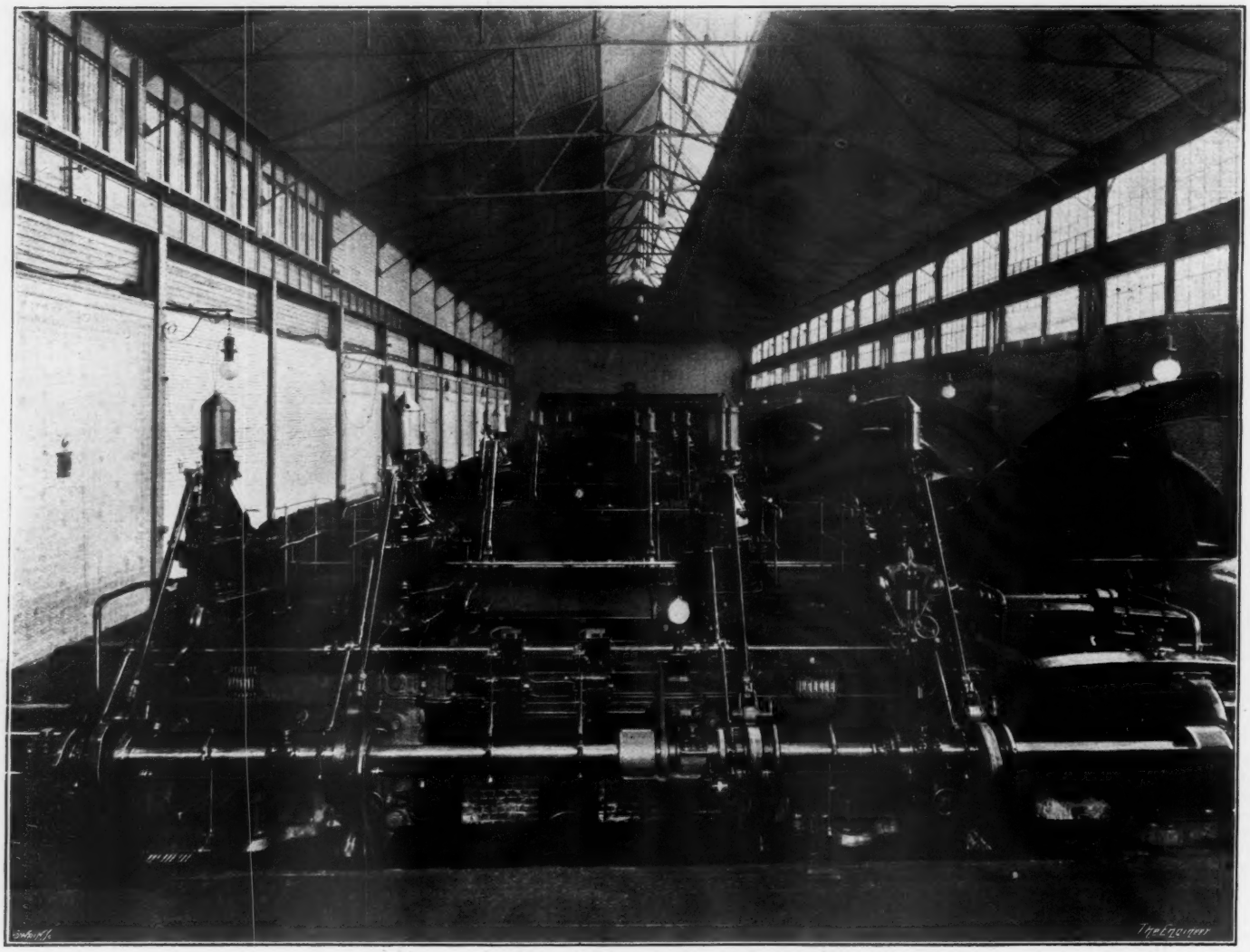


Fig. 7—GAS ENGINE POWER HOUSE

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H.M.S. BELLEROPHON.

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TO CORRESPONDENTS.

☞ *In order to avoid trouble and confusion we find it necessary to inform correspondents that letters of inquiry addressed to the public, and intended for insertion in this column, must in all cases be accompanied by a large envelope legibly directed by the writer to himself, and stamped, in order that answers received by us may be forwarded to their destination. No notice can be taken of communications which do not comply with these instructions.*

☞ *All letters intended for insertion in* THE ENGINEER, *or containing questions, should be accompanied by the name and address of the writer, not necessarily for publication, but as a proof of good faith. No notice whatever can be taken of anonymous communications.*

☞ *We cannot undertake to return drawings or manuscripts; we must, therefore, request correspondents to keep copies.*

REPLIES.

R. W. (Chatham).—Most of the technical schools give the class of training required, and you must select one in accordance with your means and the locality that suits you best. In London you might choose between the Technical College, Leonard-street, Finsbury: the Central Institute, South Kensington; King's College, Strand; or Royal College of Science, South Kensington, to name only a few. There is no examination for the Institution of Mechanical Engineers. We should advise you to study the conventional forms of English spelling; some professors are so prejudiced!

A. M. (Fulham).—The question you ask is difficult to answer. Under certain circumstances a good human eye can see one one-thousandth of an inch easily—as, for example, the threads of a spider's web, a very thin hair, the edge of a piece of cigarette paper, or a fine scratch on a hard surface. Copper wire No. 50 s.w.g. is exactly one-thousandth in diameter. The metallic filaments of some lamps are not much over one-thousandth. But an interval of one-thousandth of an inch can probably be seen but by very few human eyes. For example, a number of lines ruled together with intervals of one-thousandth of an inch give the impression of a grey surface. In a diffraction grating no less than 12,000 lines per inch are ruled by a diamond upon a hard surface.

DEATH.

On the 15th inst., at Colombe Lodge, Ealing, of pneumonia, JAMES MELDRUM, M. Inst. C.E., F.R.G.S., F.Z.S.

THE ENGINEER.

DECEMBER 23, 1910.

The Steel Trade Outlook.

BOTH nationally and internationally the future of the steel trade is provoking unusual speculation just now. And, indeed, the general situation cannot be viewed without anxiety. In some respects the situation is unparalleled. For once in a while we have the prospect, with a settlement of the shipyard dispute, of great activity in our home trade concurrent with great depression in America, a country which has generally taken the lead in the iron and steel industry in recent years. In Germany, too, home trade is none too brisk; and exports are being vigorously pushed in order to keep works reasonably employed. Thus, so far as domestic demand is concerned, we seem better placed than our rivals, relatively to productive capacity, at the moment. Of course, the fact must not be overlooked that our competitors have increased their capacity of production far more largely and rapidly than we have ours these last ten or twenty years. But the point of chief importance to us in this country is exportation, and in this connection the question of foreign competition merits our strictest attention. While our trade unionists by their strikes, by their "ca' canny" policy, and by their opposition to improved appliances, alike in mine and workshop; and while our politicians with their restrictive laws, such as the Eight Hours Act, and by their constantly growing pile of taxation, are hampering our industries and increasing our productive costs, the competitive struggle between nation and nation is getting keener, our rivals are getting stronger, and they are rapidly overtaking us in the international race.

But we cannot afford to be beaten in the race. On a basis of national production of iron and steel we have already descended from first to third position. Perhaps that was inevitable. Germany is bigger than this country, and it contains nearly 20,000,000 more inhabitants. The United States is far bigger than the United Kingdom, and that country has nearly 50,000,000 more people than we have. But neither size, nor population, nor natural resources provide any reason why any country should beat Great Britain in exports. Here we have a right to reign supreme. Let the situation be clearly understood. Great Britain is more a manufacturing, and less an agricultural, nation than either Germany or America. By natural resources and by virtue of the geographical extent and position of our country, by aptitude, inclination, and tradition, we are above all things a manufacturing and exporting nation. Just as we import more agricultural produce than our contemporaries, so is it necessary that we should export more manufactures than they do. If we do not produce much food, then we must produce and sell many manufactured goods, or drift to national bankruptcy. A big and progressive trade in manufactured exports is far more essential to us than to any other nation, and as the iron and steel industry is now the world's chief manufacturing trade, it follows that we must retain first place as an iron and steel exporting country, or soon cease to exist as a first-class nation. It is just as imperative that we should be supreme in iron and steel exports as in naval matters.

But our supremacy in iron and steel exports is threatened. That is the central, supreme fact in the commercial situation to-day. In the first three-quarters of the current year we have exported 3,554,000 tons of iron and steel. But the Germans, far less dependent upon exports than we are—the Germans, far more largely an agricultural people than we are—the Germans, with not nearly such colonial possessions requiring manufactures as we have—have in these same nine months exported 3,575,000 tons—metric—of iron and steel. In volume of tonnage Germany is now practically level with us in the exportation race. Yet, only ten years ago we exported very nearly four times as much as Germany. In 1900 we exported 3,213,000 tons of iron and steel against Germany's 838,000 tons. When we get the complete figures for 1910 it will probably be found that Germany has got ahead of us. Our long held supremacy will, at our present rate of progress, be gone within the next few months, if it has not already gone. In a decade the Germans have increased their export trade trade by 400 per cent., while we have not increased ours by 40 per cent. At this rate of progress, where shall we be a decade hence? While our rivals are going forward almost by leaps and bounds, we are doing little more than mark time. Relatively to the world's rapidly growing trade we are losing ground. We are losing our grip of the world's business. We have been beaten in iron production, in iron manufacture, and in steel production and manufacture, and seem about to be beaten even in iron and steel exportation—the very branch of business, above all others, in which we ought to stand supreme, unchallenged. Relatively to the world's demand, and comparatively to the progress of our rivals, we are going backward. We are being overtaken and outdistanced by competitors whose iron is no better, whose coal is not so good, and whose geographical position is not nearly so favourable as our own. Moreover, as already mentioned, we are being beaten by rivals not nearly so dependent upon exportation as we are.

In view of our favoured position in the matter of exportation facilities, in view of our great dependence upon iron and steel exports, and in view of the fact that a foreign country has this year, for the first time in history, just about drawn level with us in the race, it is not too much to say that we have arrived at a critical stage, if not a crisis, in our commercial development. Yet this is the time chosen by trade unionists and politicians to impose additional fetters and restrictions upon our industries. Our skilled workmen violate solemn industrial treaties. Our miners refuse to work on the multiple shift. They kick against improved appliances. They refuse to make the best of new contrivances. They strike over the most trifling matters, and in defiance of their own leaders. They break their agreements with bewildering frequency. It is necessary to call in the military to prevent the flooding of mines. On top of all this the politicians impose Eight Hour Acts, and screw increased taxation out of our industries to finance such doubtful "social reforms" as labour exchanges, for example. Not only does our Government refuse to grant industry any protection from unequal competition, or any encouragement such as is afforded by most foreign Governments, but it seems never so happy as when it is taxing and hampering our industries. With hostile trade unionists on one side, hostile politicians on the other side, and subsidised, bounty-fed foreign competitors in front, the wonder is not that we are being elbowed out of the international race, but that we are not kicked out. Such are our natural resources as an iron and steel country, such is our geographical situation for assemblage and shipment, and so vital is the importance of our retaining the leading position as an iron and steel exporting country, that we ought not to allow any other country to come anywhere near us in this business. The world's demand for iron and steel products is rapidly increasing; therefore, our export trade in these products should be rapidly increasing. And we venture to say that it would be rapidly increasing if trade unionists and politicians would give our industries a fair chance in the international competitive race. When this year's export trade is officially recorded, and it is found how seriously we

are challenged by our foreign rivals, we trust that the figures and their significance will be deeply pondered in labour and political circles.

Automatic Signalling.

Collisions such as that which took place recently at Willesden Junction direct attention to railway signals and their imperfections. In this case it will be remembered one passenger train ran into the tail of another which was standing at the platform. The second train had passed a signal intended to protect the first. Whether that signal was or was not at danger remains to be seen. Not long before, on another line, a train ran into a light engine the presence of which the signalman had forgotten—a by no means unprecedented event. We have in such cases mental, not mechanical, failure. The signalman has admitted that he made a mistake at Willesden, and there is also no question as to the reason why the first collision took place. As all such evidence goes to show that men are not infallible whatever their experience, it is quite natural that attempts should be made to supplement human intelligence by automatic mechanical agency.

Just at the moment the appearance of an exhaustive paper on "The Overrunning of Signals Standing at Danger," by Herr Horgen, a German engineer, is quite opportune. The paper forms a communication to the pages of the *Zeitung des Vereins Deutscher Eisenbahnverwaltungen*; an excellent translation of it will be found in the November Bulletin of the International Railway Congress Association. It is often stated by disappointed inventors that they cannot get a hearing; and that railway officials in particular will not listen to them. This certainly cannot be said of German railways, on which exhaustive attempts have been made to get some practical means of automatically attracting the attention of the driver who is running past a signal at danger. As far back as 1901, at the invitation of the German State Railway Office, representatives of nearly all the German States met to discuss the question, the Austrian Railway Ministry co-operated, and several experiments were tried. In 1904 there was a meeting of the Technical Committee, held in June at Trier, when eight conditions—far too long for reproduction here—were laid down which an automatic signal must satisfy. The resolutions were confirmed at Danzig in September, 1904. A great many inventions were submitted during the following two years, but until 1906 nothing worth trial was brought before the Committee. Then a few were deemed worth further consideration, and were made the subject of experiment. Up to the present, however, the problem remains unsolved on the continent. The best results so far appear to have been obtained with double light distant signals; and according to the decision of the Council of 10th March, 1910, this pattern of distant signal is to be substituted for that formerly used. The results obtained in Saxony and on several large trial sections on the Prussian State Railway prove beyond doubt that the perceptibility of the distant signals in the night time is materially improved by this arrangement. It is to be expected that this alteration will be completed in a few years; the limit fixed for carrying it out is the end of 1919. Nothing is said, however, about signals in the daytime.

The difficulties lying in the way of mechanical signalling which shall be intensely operative on the footplate are numerous, and of a kind quite easily overlooked by those who have had little or no experience of the working of railway traffic or the movement of trains. Thus, for example, one promising system of putting detonators on the rail failed because it interposed an undesirable resistance between the signal-box and the semaphore. A species of syren blown by compressed air and attached to the signal-post failed. It was heard by the drivers of goods trains, but the noise on the footplate of fast passenger engines was so great that the syren was rarely audible. Besides this, persons living near a busy station objected to the continual whooping and hooting. Turning to electricity, we find that insuperable objections appear to exist to the use of all kinds of direct contact-makers, such as light wooden rods to be broken by impact. Steel wire brushes answered best; but it was soon discovered that the oscillation of the engine brought them against guard rails and points. The brushes are, however, still being tried in Hanover. Two express, two passenger, and two goods locomotives have been fitted with brush contact-makers. It is found that at high speeds the mechanism sometimes fails to act, and the brushes are constantly injured by ballast and other things projecting inside the boundary of the loading gauge. Trials with the Van Braam apparatus are being carried out on the Prussian State Railway. Ten express engines have been equipped in the Halle district alone. It consists of a pair of slippers mounted on the engine. If these come in contact with treadles raised by the signalman a trigger is released, and a signal shown on the engine, or the continuous brake may be put on. But the slippers are often broken, and much difficulty is experienced in winter, as in frosts the treadles cannot be worked with certainty from the signal-box.

The position is very simple. We have a train moving at a high speed. There is no trouble at low velocities—at least in summer. How is communication by contact to be made between the engine and the signal-box? All the difficulties must be carefully thought out before any success can be achieved in overcoming them, and many are of a sort not anticipated. Take, for example, the use of treadles, or rising and falling bars, just inside or just outside the rail. A speed of 60 miles an hour is 88ft. per second. If the treadle bar is 10ft. long, the time of contact will be only 0.11 of a second. What can be done over and over again with unfailing certainty in so minute a fraction of time? Again, direct contact is so violent that it is impossible to prevent the smashing of the parts coming in contact; even if they are fitted loosely the inertia of the thing struck is sufficient to cause a violent shock. It is to be remembered that the effect is just the same as if the moving element had fallen from the top of a tower 120ft. high. Nor must we forget that the apparatus may be extremely accessible to anyone moving on the line or disposed to tamper with it. It is, to say the least, an interesting fact that, in spite of the exertions of hundreds of inventors, no automatic device for preventing the overrunning of signals has yet got beyond the experimental stage after nearly half a century of effort. The only exception we know is to be found on the North-Eastern Railway, where a system, fully described in our issues of January 17th and 31st, 1908, has been in successful operation for nearly two years. On the Great Western, also, some success seems to have been secured. There is, moreover, one obstacle in the way that no invention can possibly get over. It is the fear that the use of automatic signals would render drivers careless. If a man feels quite sure that he will be made aware in a very unmistakable fashion, of the fact should he run through the signals, it is not unlikely that in process of time he will cease to use his eyes, and no longer look out for danger. Then one day the automatic mechanism fails, and there is a collision. This is a reason why railway authorities are lukewarm. Even if all mechanical difficulties had been overcome, the question would still arise, is it better to trust to machinery or to brains? Which of the two is the more likely to fail now and then? On the whole we agree with those who seem to pin their faith on the making of the distant signal more obvious than it is now. At night there would be little difficulty in this. Nothing more is required than a lamp sufficiently powerful, like, for example, the head light of a motor car. What is to be done in the daytime is not so easily settled. Furthermore, we have always the fact before us that men have ere now driven in moments of mental aberration right through signals which they saw plainly, although for the one unlucky moment these had lost their significance. It is a recognition of this fact that causes the invention of devices for shutting off steam and applying brakes automatically, to which there are, nevertheless, very strong objections.

Manchester's Atmosphere.

Probably no community in these islands is better served by its authorities with regard to the high standard of purity of its food and water supplies than Manchester, but there is one other equally important respect in which the attitude of the City Fathers is far from satisfactory. We allude to the gas supply. The disregard of the Corporation of the demand of its citizens for an amelioration of its atmospheric surroundings is little short of amazing. As everyone knows, the chief cause of the pollution of the air in large centres of population is the domestic bituminous coal fire. Compared with this, the smoke from factory chimneys is only of secondary importance. Mr. Robert Clayton, president of the Society of Chemical Industry, has estimated that the smoke nuisance costs the Manchester ratepayers something like £500,000 per annum in cleansing materials, wasted labour, wear and tear, &c., to which has to be added the annual loss of life due to respiratory diseases. In spite of these deplorable facts, the Corporation insists on putting a ridiculous premium on the price of its gas, in order that a sum of something like £50,000 may be devoted to the relief of the rates. Much as the average Briton loves his uneconomical coal fire, it is recognised on all hands that the solution of the smoke nuisance is largely dependent upon its abolition, in towns at any rate, and practically the only alternative yet available is the gas fire. Mr. Newbigging, the Manchester gas engineer, recently expressed the opinion that "every difficulty in the way of a cheap distribution of gas and electricity should be abolished, and to effect this cheapness he would rather see gas and electricity undertakings rate-aided than rate-aiding." Mr. John Burns, representing the Local Government Board, has also expressed himself similarly with regard to the smoke nuisance. The present price of gas is 2s. 3d. per 1000 cubic feet in bulk, and about 2s. 10d. when sold through slot meters—prices which compare very unfavourably with that of coal for heating in Manchester. At a meeting of gas engineers held in that city about three years ago a well known authority on gas manufacture stated that in a town where the householder pays 2s. 2d. per 1000 cubic feet, gas could be profitably sold to large consumers at 1s. 6d. It was not stated whether this figure referred to enriched gas if so an even lower price might be mentioned for the unenriched article, which answers equally well for incandescent gas lighting, and is even superior for heating purposes. In the face of these figures, coupled with the experiences of some other towns—Aldershot, for instance—it is time that the inhabitants of Manchester demanded from the Corporation a reconsideration of its attitude with regard to this all-important matter, both on the grounds of public health and real economy.

Awards at the Buenos Aires Exhibition.

We have received what is described as a provisional list of awards made to British exhibitors at the recent Exhibition at Buenos Aires. We do not know what "provisional" may mean, but if it signifies that still further awards are to be made it only emphasises more strongly what we are about to say. So far as our information goes, we believe that there were 234 separate British firms exhibiting. There have, up to now, been 212 awards of various grades to them made public. Analysing these we find 81 Grands Prix, 72 gold medals, 33 silver medals, 12 bronze medals, 13 diplomas of honour, and one honourable mention. This does not quite mean that 212 out of 234 have obtained mention in some form or another, because some have more than one award, but it indicates that the proportion is very high—too high, we venture to think, to be quite a genuine representation of the facts. In this we must not be taken as meaning in any way to detract from the value of the British goods shown; far from it. We know that they were excellent; but, granting that the Grand Prix is a recognition that the exhibit to which it is awarded is the very best of its kind, how, without some indication of bracketing, can Grands Prix be given to more than one exhibit of the same class of article? The answer is, we are afraid, only too well known. It is that if a firm has once obtained a Grand Prix at any international Exhibition it is at any subsequent Exhibition awarded a Grand Prix by way of courtesy. This, to our mind, stultifies the whole idea and object of awards, and will, if continued, most probably react on the quality of the goods exhibited. If a man knows he will get a Grand Prix, whatever happens, he will assuredly not take so much pains as he who still has that laurel to win. The whole business has now degenerated into a farce. At Buenos Aires there were more Grands Prix than gold medals, more gold medals than silver, more silver than bronze medals. The Grand Prix no longer means what it did, and its award is not nearly the distinction that it once was. It is the same with the gold, silver, and bronze medals. We hold, and we believe that the whole body of manufacturers would agree with us, that each Exhibition should be taken as a separate unit, and the awards made irrespective of what may have gone before. Such awards would be worth vastly more to their receivers, and the healthy competition which would ensue would make for improvement all round.

The Mechanicals and Metallurgy.

Last Friday evening there was a large attendance at the Institution of Mechanical Engineers,

when two papers of a professedly metallurgical nature were down for reading. The first of these papers, that dealing with the production of high-pressure castings in gun-metal and bronze, we shall print in due course, and the discussion, such as it was, which it provoked is reported elsewhere in this issue. With regard to the second paper, its subject, "The Constitution of Troostite and the Tempering of Steel," is an exceedingly abstruse one, and the paper is not reprinted. We may add that the author treated his subject with full-robed dignity and made no attempt to present his facts in any language other than that of the scientific metallurgist. Now, we submit that from the academical point of view, or even from that of the practical steelmaker, it may be an interesting and important point to settle whether martensite is or is not a solid solution of carbon in β iron. To establish the fact that troostite consists essentially of α iron in the amorphous condition, and that it contains carbon in suspension, and not in solution, as carbide of iron, may be a noteworthy advance in metallurgical science. But that it is a fit subject for discussion before such a body as the Institution of Mechanical Engineers we cannot believe. Metallurgy, with its weird symbols and signs, its cumbersome terminology and its perplexing theories, is of all sciences, except perhaps crystallography, most difficult of entry by the outsider. Yet its direct bearing on practical engineering is of the last importance. If we take the subject of tempering tool steel alone there are a thousand and one points on which the practical engineer wants enlightenment from the metallurgist. It is not, of course, to be assumed that such enlightenment could invariably be given, but there is no doubt that stripped of its technical formalities a practical acquaintance with modern metallurgical theories, particularly with regard to iron and steel, would form a handsome addition to the engineer's stock of knowledge. We quite agree with Dr. Hele-Shaw, therefore, that the Council of the Institution would do a popular thing if they would arrange for a lecture on the present state of knowledge regarding carbon in iron. Every subject is capable of being presented in many different ways, and we trust that if the proposal be carried out the Council will see to it that the lecturer is chosen in the first instance because he has a wide and practical knowledge of mechanical engineering, and only in the second because he is a metallurgist.

THE DESIGN OF SCREENING PLANTS FOR OLD AND MODERN COLLIERIES.

By J. S. BARNES.

No. 1.

ONE of the chief objects at every modern colliery in practically every coal-field in this country is to procure the most economical and satisfactory method of sizing, sorting, and cleaning the coal or other mineral with machinery and labour-saving devices, and to deal successfully with a large output with a minimum of labour and other costs. The screening arrangement requires careful designing to procure the desired economy, and at the same time to avoid unnecessary complications, and obtain everything of maximum efficiency and strength. It becomes essential to consider, at the commencement of the design: (1) the tonnage to be dealt with by the plant in a given time; (2) whether this output will be all one kind from one seam, or from different seams; (3) if different, the various kinds and number, and whether these are to be filled into the trams separately or together in the pit; (4) the proposed number and sizes of the various sorts of coal or other mineral; (5) the method of transit of the trams to and from the cages to the weigh bridge, tipplers and screens; (6) the kind of tipplers, conveying belts, and screens to adopt; (7) the general arrangement and kind of structure; (8) the arrangement of the sidings, and number of wagon roads to accommodate the necessary sorts of coal or other minerals; (9) the height at which to fix the various machinery and apparatus; (10) the amount of storage or spare plant, if any, to provide for; (11) the provisions for any possible extensions; (12) the method of driving and the motive power to adopt.

In this article no attempt will be made to go into a great variety of different screening plant details and arrangement. It is proposed to deal briefly with a plant recently designed by the writer. This plant is now successfully working, and eventually will deal with 6,000 tons of coal a day from two seams. The general arrangement of the screens and structure is shown in Figs. 1, 2 and 3 in our 2 pp. supplement, which are respectively plan, side and end elevations. The building structure throughout is composed of rolled steel joists, the six rows of columns being of 12in. by 6in. at 54lbs. per foot run joists where these are directly under the screens, and tipplers—marked A in the plan—and 10in. by 5in. at 32lbs. per foot run elsewhere. The length of the building is 138ft. in the direction of the wagon roads, and at right angles to these roads the width of the building is 136ft. The height to the eaves is 34ft. 4in., and the extreme height of the roof is 51ft. 10in. Each 10in. by 5in. column is provided with specially-designed and constructed steel plate foundation bases, as shown in detail in Fig. 5. For the 12in. by 6in. columns the foundation base plates are in two portions, as shown in Fig. 4. Each column is fixed on, and buried in concrete up to rail level, so as to prevent the base plates from being dangerous to the wagon attendant. The proportions of the concrete are 1 of sand, 1 of cement, and 1 of broken furnace slag stones. The holding down bolts are partly rag bolts, and partly with plates and boxes built round them. The foundation of each column was set out with the theodolite level and staff, so as to get accurate squares, and true levels.

The buildings throughout are covered with corrugated sheeting, No. 18 B.W.G., secured to purlins of 3in. by 3in. by $\frac{3}{8}$in. angles, by means of $\frac{1}{2}$in. galvanised bolts and nuts. These purlins are fixed both horizontally and vertically, and are specially arranged for window openings. The floor joists are made up of 8in. by 4in. at 19lbs. per foot run rolled steel joists with special wood runners 3in. thick bolted thereto by flat-headed bolts. Planks 11in. by 3in. are nailed to these runners, to form the floor. The belt house floor is level, but the top or tippler floor is arranged with various gradients, so that the trams may travel without any hand labour. These gradients are shown in Fig. 1. The direction of the travelling trams is indicated by arrows. The full trams gravitate to the weigh bridge and tipplers, and the empty trams are elevated again by means of a creeper. A specially-designed automatic kep lever engages with the axles of the full trams, and operates the catches in the cages for releasing and holding in the trams. The keps are McBeam's patent, and are arranged to tilt the cage bottoms to a gradient of 1 in 36. When the cages drop on to the keps, they have not to be raised off the keps, when it is desired to lower the cages down the shaft. The tipplers are arranged to work automatically, the full tram knocking out the empty tram by an arrangement of catches and levers. The tipplers are set in motion by means of the empty trams operating the starting gear. This device is Messrs. Head Wrightson's patent. The coal then passes over a jigging screen shown in Fig. 14. The length of the perforated plates is 16ft., and the width 7ft., which gives a total screening area of 112 square feet, and the trams hold 16 to 17cwt. of coal. If we regard the whole of the screen area as being covered with the coal from one tram, we should have an average thickness of coal of 3$\frac{1}{2}$in., but, of course, some of this drops through the first perforated plate, and hence the above thickness would be less. Since, however, the second tram is tipped on to the screen before the screening is completed from the first tram, the above thickness of coal is twice as great as the figure given.

The coal passing through this screen falls on to a dead plate, fixed directly beneath the perforated screen plate, whence it is jigged on to a back shoot, and then conveyed by means of a canvas belt, at right angles to the railway sidings. This belt, which is 36ft. long by 3ft. in width, then delivers the mixed coal, *i.e.*, all below 1$\frac{1}{2}$in., on to a canvas belt, 124ft. 6in. long by 3ft. wide, which travels parallel to the railway sidings. At the end of this belt, the mixed coal is again screened by means of a revolving screen outside the main steel building,—not shown on the drawings,—and all below $\frac{7}{8}$in. is then taken to a large washing plant. This plant, designed by the writer, can wash 1,000 tons in a day of eight hours, and has bunker storage for 1,000 tons. Returning now to the coal passing over the screens next the tipplers, it will be seen that it passes on to a steel plate belt, termed the inspection belt, the design of which is shown in Fig. 18. This design is Kock's Patent, and is manufactured by Head Wrightson & Co., Ltd. The coal on this belt can be easily inspected for any dirt, and laid out for the check-weighman to see. This belt is inclined, so as to get the height necessary for delivery on to the second set of screens. The length of these screen plates is 8ft. 3in., and the width 6ft., giving a screening area of 49$\frac{1}{2}$ square feet each. The perforations are 3$\frac{1}{2}$in. round holes. The coal dropping through this screen, passes on to a steel plate conveyor 25ft. long by 4ft. wide, and from there on to the Trebles steel plate conveyor belt, for cleaning and picking purposes. This belt is 55ft. 2$\frac{1}{2}$in. long by 4ft. wide. From the second screens, all sizes of coal above 3$\frac{1}{2}$in. pass over on to the Best coal-conveying belts. The short cross-belts are ordinary steel plates, as shown in detail in Fig. 20, and the Best coal belts are Kock's patents.

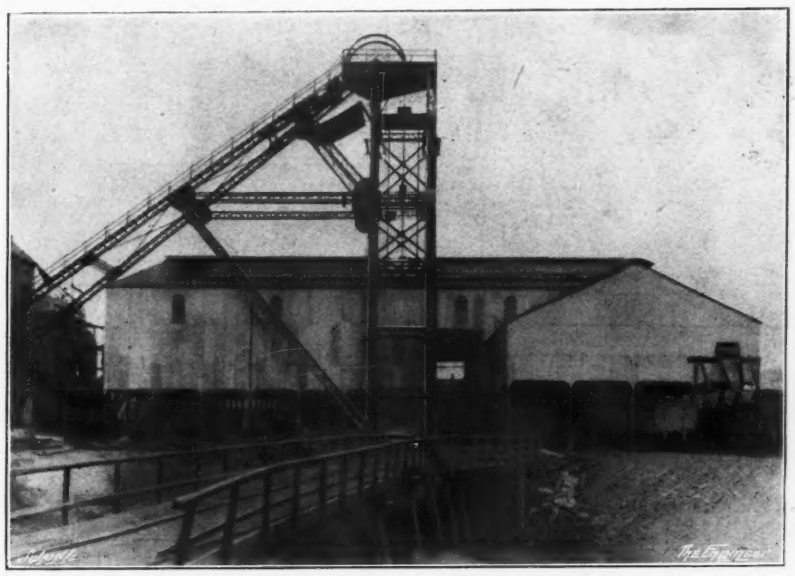
The Best and Trebles coal belts each have an ordinary movable swing arm of 15ft. radius, and are raised and lowered by means of worm and worm gear, driven by power, and operated by a hand lever and friction clutch, shown in Fig. 15. The two tipplers can deal with 3,000 tons of coal in eight hours. Eventually another seam will be worked, at the same time. Additional tipplers and screens will then be fixed between the already erected portions of the tippler and screen house. The remaining portion of the belt house can easily be added, as it is already designed, and holes have been left in the existing columns for jointing up. The speed of the tipplers is three revolutions per minute. The speed of each screen is 37 to 64 jiggs per minute, and the eccentrics are arranged with variable throws of 3in. to 6in. A 10cwt. fly-wheel is attached to each eccentric shaft of the jigging screens. The speeds of the various belts are as follows:—

Best coal belt	... ...	45ft. per minute.
Cross " "	... ...	50ft. " "
Cross canvas belt...	...	150ft. " "
Long " "	... ...	150ft. " "

The long canvas belt will convey 1,000 tons of coal in eight hours to the washery. All screens, conveyors and tipplers are arranged to be thrown in and out of gear by means of friction clutches. All journals are brass-bushed throughout the entire plant, and all the gearing is of cast steel. The whole plant is driven by means of three phase alternating current, generated from three turbines of 400 kilowatts capacity each. These turbines also provide the power for haulage, coal-cutting and pumping, and all other power purposes except winding.

The whole of this scheme was planned, designed, and set out by the writer to the general instructions of F. J. H. Lascelles, Mining Engineer, and the work was contracted for and executed throughout to the satisfaction of the Carlton Iron Co., Ferry Hill, Durham, and of Head Wrightson & Co., Ltd., Stockton-on-Tees.

In a succeeding issue the author purposes entering into a consideration of the general principles governing the design of colliery screening plant.



SCREENS AND HEADGEAR AT MAINSFORTH COLLIERY

BOOKS RECEIVED.

Irish Railways and their Nationalisation. By Edwin A. Pratt. London: P. S. King and Son, Orchard House, Westminster. Price 6d. net.

Rock Drills. By E. M. Weston. London: Hill Publishing Company, Limited, 6, Bouverie-street, E.C. Price 17s. net.

Heat Engines. By J. R. Allen and J. A. Bursley London: Hill Publishing Company, Limited, 6, Bouverie-street, E.C. Price 12s. 6d. net.

Contracts in Engineering By J. I. Tucker. London: Hill Publishing Company, Limited, 6, Bouverie-street, E.C. Price 12s. 6. net.

Elementary Crystallography. By W. S. Bayley. London: Hill Publishing Company, Limited, 6, Bouverie-street, E.C. Price 8s. 6d. net.

Practical Shaft Sinking. By Francis Donaldson. London: Hill Publishing Company, Limited, 6, Bouverie-street, E.C. Price 8s. 6d. net.

A NEW AUTOMATIC FLASHING LIGHT.

FOR a number of years now the Trinity House authorities have been endeavouring to produce a flashing light which would not require the continuous presence of an attendant, but which would light and extinguish itself at the proper times all the year round, and also revolve the necessary lenses at the required rate. The first step in this direction was the unwatched flashing gas-lighted boat which we were enabled to illustrate and describe in our issue of August 27th, 1909.

Fig. 1—THE COMPLETE LIGHT

In this case there were automatically revolved lenses, but the light, which was of the Argand type, was always burning, and, hence, using up gas. Still another step was the introduction of a timing mechanism by means of which the gas could be turned on and off at varying times of the day and night, according to the period of the year.

Hitherto, however, there has not been one single apparatus which would (1) turn the gas on and off at the proper times; (2) give a flashing light; and (3) only require attention at protracted intervals. We were recently invited to inspect, at the Trinity House Wharf, an apparatus which combines all these attributes, and we propose to describe it in the following article.

The matter has occupied the attention of the Engineer's Department of Trinity House for a considerable time past, and it was determined, if possible, to devise an apparatus which, in addition to embodying a mechanism similar to that installed in the unwatched gas-lighted boat above referred to, should be so arranged that the clock for turning the gas on and off at the proper times should be wound by the apparatus for revolving the lens.

small gasholder on the left-hand side is only being used temporarily. The actual reservoir to be employed is considerably larger, and is arranged underneath the apparatus, which has been fixed on a masonry pedestal in an isolated position in the Bristol Channel.

The method on which the mechanism works will be readily understood by reference to Fig. 2, which is a reproduction of a photograph taken of the interior of the casing underneath the lantern, it being possible to expose this by opening the door marked A in Fig. 1. In Fig. 2 the gas, after passing through a valve—which is not shown in Fig. 2, but may be seen on the ground in Fig. 1, and which reduces the pressure of the gas stored in the reservoir at high pressure to a pressure of about 2 lb. per square inch—enters the apparatus through the pipe B, which is provided with a tap. A gauge is arranged inside the apparatus to show that the correct pressure is applied. This pipe B is connected to a micrometer valve C, which can be accurately adjusted to pass just the correct volume of gas necessary to work the apparatus at its proper speed. Two cylinders, D and D^1, are arranged side by side. These are of metal and they are fitted with diaphragms of specially prepared flexible leather which form their covers. On the top surface of each diaphragm is a circular plate of flat metal of lesser diameter than the diaphragm, but still of con-

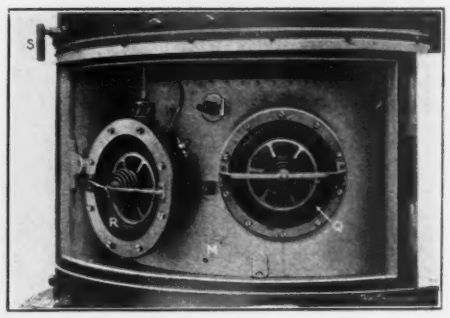


Fig. 3—PRESSURE CONTROLLING VALVES

siderable surface, so as to give as firm a footing as possible to the upright rods F and F^1, which are attached to the circular plates just mentioned. These vertical rods are at their tops pivoted one at each end of a centrally pivoted weigh-beam, or rocking lever, which is barely visible in the engraving by reason of its being hidden by other parts of the mechanism. The cylinders D and D^1 are provided with inlet and exhaust valves, which work in conjunction with one another, and are so adjusted that when the inlet valve of cylinder D is open the exhaust from this cylinder is closed, whereas at the same time the inlet valve of cylinder D^1 is closed and its exhaust opened.

Now, supposing the gas to be turned on, it will first of all enter the cylinder D through the valve C. As it does so it will distend the flexible leather diaphragm and will cause the rod F to be pushed upwards. In doing this it will cause the rod F^1 to be depressed, since each is at the opposite end of the same weigh-beam. Consequently any gas that might have been in the cylinder D^1 is ejected through the pipe E^1. The rod F having reached its highest permissible point, an automatic mechanism comes into play which simultaneously closes the inlet valve and opens the exhaust valve of cylinder D. The same motion opens the inlet valve and closes the exhaust valve of cylinder D^1. The consequence is that the gas, instead of entering cylinder D, passes through the pipe E and enters cylinder D^1. This causes the rod F^1 to be forced upwards and the rod F downwards, so that the gas which had entered cylinder D in the first instance is in its turn ejected through a pipe at the back, which, however, cannot be seen.

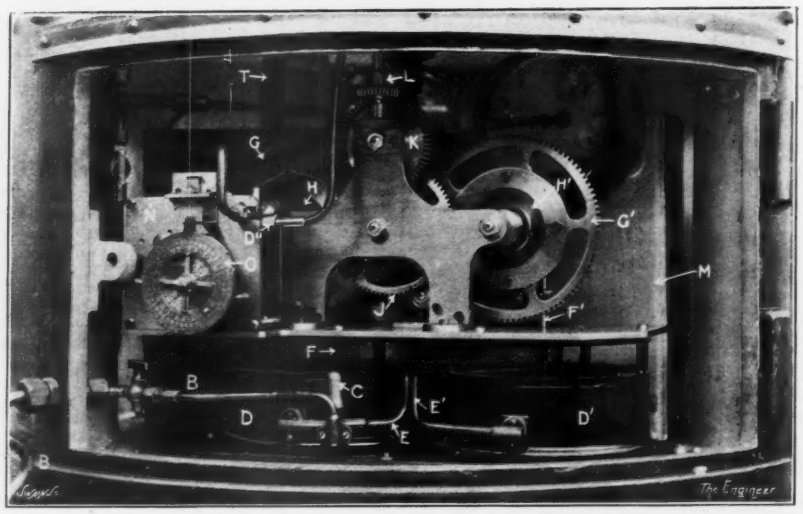


Fig. 2—THE TIMING CLOCK AND DRIVING MECHANISM

Acting on the instructions and according to the suggestions of Sir Thomas Matthews, Chief Engineer to the Trinity Brethren, Mr. F. G. Attwood, the assistant superintendent of the Corporation's workshops at Blackwall, some time ago now started to work out the problem, and his efforts have met with a remarkable degree of success. The apparatus produced is entirely automatic, and it is, moreover, wonderfully simple and, as far as can possibly be judged without extended trial under service conditions, not likely to get out of order. A view of the complete plant, as erected for preliminary testing at the Trinity House Wharf at Blackwall, is shown in Fig. 1. The

Before going on further to discuss the mechanism we may trace the course of the gas after it leaves the cylinders D and D^1. Were it not for the provision of some sort of reservoir a light supplied with gas from these two cylinders would certainly show pulsations. Accordingly the gas is first of all led into a vertical pipe T, which is of fairly large diameter and which leads through a valve Q—Fig. 3—into a sheet metal reservoir M. The valve Q is set to cut off the admission to the reservoir when the pressure reaches 13in., and the mechanism is automatically stopped. The valve is simply a cylinder with a flexible leather cover on which a spring

presses, and the action will be quite well understood from an examination of Fig. 3. In this view there is also another valve R. This works on precisely similar lines to valve Q, and is simply added as an additional precaution. It is in communication with the tank or reservoir M, and should the pressure in the latter rise to as high as 14in. it opens and allows gas to escape to the atmosphere through the nozzle S. From the reservoir M the gas when the apparatus is at work passes to the burner, which is adjusted to operate at a pressure of 11in.

We can now return to the mechanism, and to commence with it should be explained that its main objects are two-fold—first, to turn on and off the gas at the correct time, and secondly, to revolve the lenses in the lantern. Both objects are achieved by a remarkably ingenious, but at the same time simple, combination of mechanism. In the first place, attention must be drawn to a special form of clock N. This, instead of hour and minute hands, is provided with two dials O, one of which is divided into 24 divisions, representing the hours of the day, and the other has 12 divisions, representing the 12 months of the year. These dials are ordinarily clamped so that they work together, but they can, for setting purposes, be released and moved by hand. There is a fixed pointer, and if the dials are set to the day of the month and time of day, the mechanism will, within certain limits,

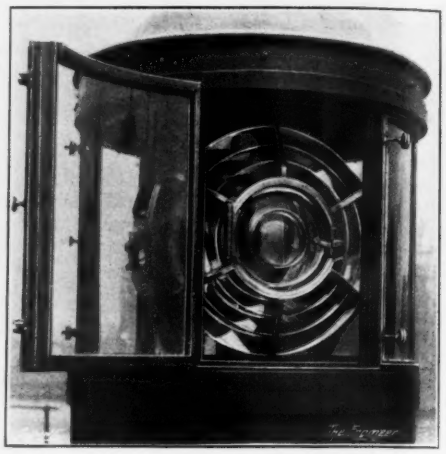


Fig. 4—THE LENSES

light up and extinguish the lamp at the correct time each day, making the necessary variations for the time of year. A margin of half an hour is allowed at each end so as to be certain that even if the clock gain or lose a little, the light may always be burning during the hours of darkness. It would be impossible to explain in detail exactly how the turning on and turning off mechanism operates; but it is quite sufficient to say that the action depends on the revolution of a cam, and that the shape of the cam is automatically altered by the movement of the clockwork, so that the gas remains turned on for a longer or a shorter period, depending upon the time of the year. It should be explained that a small pilot gas jet is kept constantly burning just beneath the mantle of the burner, which is of the inverted type. As soon, therefore, as the gas is turned on the burner is lit. The actual turning on and off of the gas is brought about by means of a valve at D^{11}. This is quite a small thing, and it is actuated by a lever working in connection with the cam mechanism just alluded to.

The clock is worked by means of a spring, and it was deemed expedient that the winding up should be performed by the action of the mechanism, and not to trust to periodic winding by visiting attendants. The winding is brought about in the following manner:—From the ends of the weigh-beam or rocking lever—already mentioned as being connected to the rods F and F^1—connecting-rods are taken to crank pins on the hubs H and H^1 of toothed wheels G and G^1, which

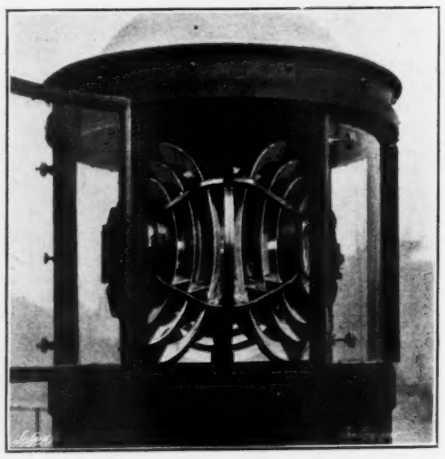


Fig. 5—THE LENSES

hubs are formed of standard bicycle free-wheels, so that as each connecting-rod is forced upwards its particular toothed wheel is revolved through a small arc, and as the connecting-rod is drawn downwards by the action of the weigh-beam the free-wheel comes into play and the toothed wheel is not drawn back with it. The result is that both the wheels G and G^1 are alternately receiving impulses which cause them both to revolve in the same direction. The reciprocating motion of one of the connecting-rods is also utilised to transmit

motion to another connecting-rod which acts on the spring wheel of the clock through a ratchet motion. When the winding is within a half turn of completion a slipping arrangement comes into play and the winding is stopped. The clock always keeps going, even when the mechanism stops, for the spring has been made of such capacity as to provide an ample margin of running time.

There remains to be described the mechanism for revolving the lenses. The motion is obtained in the first instance from the two toothed wheels G and G^1, which, it will be remembered, are made to revolve in the same direction They both gear with a pinion which is on the same spindle as the toothed wheel J. This in its turn meshes with a pinion on the same spindle as the bevel wheel K, which gears with the bevel wheel L. At the top end of the spindle carrying the latter wheel is a pinion which gears with the circular toothed rack on the revolving table carrying the lenses. This is floated on mercury and guided by rollers in the usual way, and calls for no comment.

It will have been understood from the foregoing that the whole mechanism, as well as the lighting of the lamp, depends on the turning on of the gas by the clock. As soon as this occurs the gas enters the burner and is ignited by the pilot light. Simultaneously the gas enters the cylinders D and D^1, the mechanism is started, and the lenses begin to revolve. The whole thing is as beautifully made as it is ingenious, and when once the micrometer valve C is set, so as to pass the proper quantity of gas, the lighting and extinguishing is effected at the correct times, and the lenses are made to revolve at the requisite speed. We understand that the quantity of gas which will be contained in the reservoir will be sufficient to keep the light at work for some four months. We may add that whereas the intensity of the light which this new apparatus has supplanted was 130 candles, the intensity of the new beam of light with each flash is 8500 candles. The dioptric apparatus was constructed from the designs of Sir Thomas Matthews by Messrs. Chance Brothers and Co., Limited, the well-known lighthouse engineers, at Birmingham, and the whole of the clockwork and mechanism at the Trinity House Workshops at Blackwall.

We are enabled to reproduce in Figs. 4 and 5 views of the lenses taken in two positions.

DOCKYARD NOTES.

A STATEMENT has been made by the *Zeit* as to the new naval programme to be submitted by Admiral Count Montecuccoli to the Austro-Hungary Delegations next January. It is said that the programme will extend over a period of five years, and that its execution will be calculated to cost £12,500,000, or an average of £2,500,000 per annum. For 1911, however, little more than £2,000,000 will be claimed. The £12,500,000 will represent the cost of the first division of four Dreadnoughts, including the two now building at Trieste, and of three fast cruisers of the type of the Admiral Spaun, which was recently put into commission; and of the reinforcement of the torpedo boat and submarine flotillas. The third Dreadnoughts will be laid down at Pola as soon as the 1911 estimates have been adopted by the Delegations in January or February; and the fourth, not at Fiume, as hitherto supposed, but in the yard of the Stabilimento Tecnico at Trieste, as soon as the first Dreadnought can be launched next spring. All the Dreadnoughts of this division will be of the same type; that is to say, displacement, 22,000 tons; length, 160 m.; turbine engines of approximately 50,000 indicated horse-power; speed, 23 knots; main armament, twelve 12in. guns, mounted in four turrets on the centre line.

ON the basis of Count Montecuccoli's statements during the recent Delegations, the *Zeit* indicates that two further Dreadnought divisions of four ships each must be built before 1925 if the Austro-Hungarian Navy is to attain the Tegetthoff standard of 15 or 16 first-class battleships, which Admiral Count Montecuccoli expressly declared to be the goal of his efforts.

THE United States Navy Department has drafted its Estimates in complete accordance with the Navy Law. They amount to £22,500,000, and have reached their highest point. The Estimates for 1911 will include the last of the first instalments for additional vessels, except as regards small cruisers. In 1912 the Extraordinary Estimates will show a reduction of £1,150,000, and in 1917 they will be almost entirely rid of the burden of these items. In the Ordinary Estimates the expenditure will rise uninterruptedly until 1917. The Estimates for 1911 include a loan of £4,850,000, which is £750,000 less than the loan required for the previous year. The combined expenditure for naval construction and the Canal is at the present moment at its zenith.

SHORTLY after the loss of the submarine Pluviose outside Calais Harbour a patriotic French lady, whose name has not been disclosed, offered, through the Ministry of Marine, a prize of £4000 for the best solution of the problem of saving the crews of wrecked submarines. The Ministry of Marine has now announced the conditions of the competition, which is confined to French subjects.

THE following is the programme of the acceptance trials of the new turbine destroyer Comet, now completing at the Fairfield Shipbuilding Company's Works, Govan. December 20th, official air-compressing machinery trials; 21st, torpedo trials and official balancing of electrical circuits; 22nd, ship leaves Fairfield for Govan graving dock, and has gun sights finally tested; 23rd, official electrical trials; 24th, ship undocks and returns to Fairfield; 28th, final inspection by Captain-Superintendent of destroyers; January 12th, navigating party joins ship at Fairfield Yard at 8.30 a.m., and at 10 a.m. she leaves for Tail-of-Bank to have her compasses adjusted, afterwards proceeding to sea for two hours' acceptance trial. If the trials are satisfactory, the Comet will be formally taken over on behalf of the Admiralty.

A REINFORCED concrete motor boat, 14ft. 9in. long, has recently been built in Holland. The walls, strengthened by ribs, are only 0.52in. thick. They were given six coats of waterproofing compound, and despite a number of collisions, have not leaked.

LETTERS TO THE EDITOR.

(We do not hold ourselves responsible for the opinions of our correspondents.)

THE THEORY OF SUPERHEATING.

SIR,—In your last impression a correspondent, Mr. Vernon Smith, very agreeably brings forward a question about which there has been some controversy, namely, the part played in promoting economy by the augmentation in volume which steam undergoes when superheated. Your correspondent reproduces Carnot's theorem, and says emphatically that "a study of the following figures will serve to convince the volume theorist that nothing is gained by increase of volume." Simply stated, he says that superheated steam is more economical than saturated steam only because the working limits of temperature are wider apart; the superheated steam contains more heat available for the performance of work than saturated steam. All which may be quite true, without in any way refuting the contention of the "volume theorist."

Unfortunately, vague writing and lack of perception of the vital importance of establishing mental logical concepts is as much the misfortune of science now as it has been at any previous period. A slipshod mode of thought is the result of trying to elude difficulties; and its immediate effect is slipshod writing. This is very apparent in all that concerns the transmutations of energy. Nothing is more easy than to say, as, in effect, your correspondent does, that heat energy is turned, or converted, or transmuted into work. It is quite another matter to try and form a conception of how the transmutation is effected. It is quite obvious that of all the heat energy that enters the cylinder only a portion is converted into work; and Carnot's theorem may serve well to show what percentage of the whole this portion may be. But it throws no light whatever on the details of the mechanism of conversion. A study of the literature of thermodynamics leaves the student very much where he was; for this part of the subject has no interest for the pure mathematician, and the physicist seems to have other things to think of which are more amenable to treatment, or offer greater rewards for research. But, granting the existence of at present, apparently insuperable difficulties in explaining all the mechanism of transmutation of energy, there are at least some points which are not open to doubt. We know, for example, that pressure and a piston are needed, or vanes and a current of steam. Going back further, we find that a boiler and water are necessary; and so we arrive at some settled concepts as to the mechanism by which heat is turned into work.

Mr. Vernon Smith makes the mistake of confining his attention to the cylinder of the engine. He writes as he might write of a petrol motor engine. The steam engine is a very different and, taken with the boiler, far more complex agency. The primary conversion of heat into work occurs in the boiler; and nothing in the way of work is to be had in the cylinder that did not first appear in the way of work in the boiler. The actual mechanism consists in the production of steam under pressure. I may compare it to evaporating water in a tall cylinder under a loaded piston. From first to last the heat does nothing but increase the volume of a certain substance which we call water. What we may get out of that augmentation of volume subsequently is quite another story. We must concentrate our thoughts on the central fact that the steam engine can only convert heat into work because the heat has, in the first instance, converted a cubic inch, say, of water into a cubic foot, say, of steam. That is a mechanical fact which lies at the root of the whole question. Its practical bearing is shown by the well grounded belief that the greater the volume of steam of a given pressure that can be got in return for a pound of coal destroyed by fire the better. That is why the world seeks for economical boilers—boilers that will give large volumes of steam in return for the coal burned in their furnaces.

Let me now apply this reasoning to superheating. Take a pound of steam at a total pressure of 52 lb. on the square inch. The steam will occupy 8 cubic feet. The volume of the pound of original water will have been increased just 500 times. Leaving out now for the moment all questions of expansion, we find that this steam may have lifted a piston one square foot in area from the bottom to the top of a cylinder 8ft. high, the piston carrying a load of 7488 lb. The work done would be 59,904 foot-pounds. The temperature of the steam would be 283.5 deg. Fah. Let us now superheat this steam while it is still in the cylinder until its temperature is doubled, that is, to about 568 deg. Fah. Our 8 cubic feet will now, omitting fractions, become 11 cubic feet. The piston, with its load, will be forced up a further 3ft., and an additional 22,464 foot-pounds of work will have been done. It is clear that in this case, at all events, superheating has increased the amount of work done by about 37 per cent., and that simply by increase of volume. After the whole operation is over, we have 11 cubic feet of steam to play with instead of 8 cubic feet. I am at a loss to see how Mr. Vernon Smith can reconcile this, as I hope, very plain statement of fact with the contention that increase of volume does nothing to promote economy.

Let me put the matter, however, in yet another point of view. Take the case of a boiler evaporating 8 lb. of water per pound of coal burned and giving 8 cubic feet of steam per pound of water, or 64 cubic feet per pound of coal. If, now, we superheat this steam by, say, 568 deg. Fah., we shall have, not 64 cubic feet, but 64 + 24 = 88 cubic feet supplied to the engine, the pressure remaining the same and the quality of the steam being improved. Is it not perfectly obvious from this point of view that augmentation of volume plays a most important part?

With the transmutation of heat into electrical or chemical work we are not now concerned. Its conversion into mechanical work is invariably accompanied by change in volume. To this there is absolutely no exception. Increase of pressure alone does no external work. Carnot's theorem, if read aright, refers to the changes in the volume of a working fluid possible between given limits of temperature and to nothing more recondite. This change of volume is the root concept, which once formed simplifies theories and prevents mistakes. It is quite true that we have yet to find out why making a substance hotter also makes it larger. But a good deal is gained, even though we get no further than the proposition laid down above. It is a great advance on the road to precise thought past the vague statement that "heat is converted into work in a steam engine, and the greater the range of temperature the greater the conversion."

I have referred at the outset to the existence of a controversy. It is quite true that some engineers hold with your correspondent that increase of volume does not play any part in promoting economy. But they do this on quite different grounds. In effect they say that there is no increase in volume, because the moment superheated steam passes the throttle, or, to be more exact, the moment it enters the cylinder, it loses its superheat, and shrinks to the condition of saturated steam. The question raised by this argument has, it will be seen, nothing in common with Mr. Vernon Smith's proposition, at all events so far as I understand him. It concerns, of course, the missing quantity; the effect of expansion on temperature; of water in the presence of superheated steam, and cognate phenomena. But all this leaves quite unaffected the fact that the first mechanical step in the transmutation of heat into work consists in increasing the volume of some substance. An increase in pressure is, of course, virtually due to increase in volume, a fact easily overlooked, however. In the case of the steam engine and boiler, the substance is in the boiler water; in the superheater, steam. I have said nothing of the quantities of heat transmuted in the performance of these operations, nor is it necessary that I should, though it may be noted that the quantity of heat required to augment the volume of the steam is very small as compared with that required to convert the water into steam. Nor have I said anything about Fairbairn and Tate's experiment, which show that in the earlier stages of superheating volume increases far more rapidly than in a true gas. I do not wish to confuse very simple issues.

It may be said lastly, that as regards heat exchanges in superheated engines, much remains to be learned. Valve chest temperatures can be measured. Cylinder temperatures cannot. No one knows what the temperature of expanding superheated steam in a cylinder is. It is an interesting circumstance, moreover, that loads and speeds remaining constant, the indicator cards are practically the same, whether the steam is or is not superheated. But in the latter case a smaller weight of steam is used to secure the same average pressure. This similarity of diagrams is accounted for by the fact that we have three variables to deal with, namely, loads, speeds, and pressures, and that the first two remaining unchanged, the third must also remain constant.

December 20th. SUPERHEATER.

SIR,—When writers deal with theory, as opposed to practice, they not infrequently become entangled with their own "sound reasoning," but seldom is this illustrated so strikingly as on page 655, by your correspondent Mr. Smith, who writes his theories at length to disprove, if possible, that the economy in superheated steam is due, in large measure, to increase of volume. He terms increase of volume as "absolutely erroneous," and gives the following to "confute the volume theory:"—

"The volume per pound of steam before superheating equals 3.82 cubic feet; volume after superheating equals 4.776, or an increase of 25 per cent!" X.

LOCOMOTIVES (BROAD GAUGE) OF THE GREAT WESTERN RAILWAY.

SIR,—After reading your very interesting account of these engines, I referred to a number of notes made by me in the years 1886-8 on the performances of the 8ft. single engines, which may be of interest to you. At this period the loads to be drawn were becoming too heavy for these engines, and my experience invariably was that with the 11.45 a.m. from Paddington the Flying Dutchman—which was timed to run the 77 miles 22 chains to Swindon in 87 minutes, time would just be kept with a load of five 8-wheeled broad-gauge coaches. With six coaches this timing was maintained only when the weather was fine and calm, and with seven coaches the engine was hopelessly outclassed. On one occasion with engine Rover the maximum speed never exceeded 58 miles per hour, the load being seven 8-wheelers, and four minutes were dropped from London to Swindon.

The following is a detailed schedule of the best of the various runs which I timed at this period:—

11.45 *a.m. Flying Dutchman, Paddington to Swindon, Engine Eupatoria. Load Seven 8-wheeled Coaches. September 27th, 1886.*

	h.	m.	s.	Speed, m.p.h.
Paddington ... dep.	11	45	40	—
Mile-post 23	11	51	4	—
" 19¼	12	9	12	54.4
" 22	12	12	5	57.2
" 24	12	14	22	52.6
" 25	12	15	31	52.2
" 26	12	16	43	50.0
" 27	12	17	53	51.4
" 28	12	19	5	50.0
" 29	12	20	17	52.2
" 30	12	21	30	49.3
" 32	12	24	3	47.0
" 33	12	25	18	48.0
" 34	12	26	29	50.7
" 35	12	27	39	51.4
" 37	12	29	53	53.7
" 38	12	31	0	53.7
" 39	12	32	10	51.4
" 40	12	33	15	55.4
" 41	12	34	25	53.0
" 42	12	35	31	53.0
" 43	12	36	39	53.0
" 44	12	37	43	56.2
" 45	12	38	46	57.1
" 46	12	39	46	60.0
" 47	12	40	45	61.0
" 48	12	41	45	60.0
" 49	12	42	47	58.1
" 50	12	43	50	57.1
" 53	12	47	5	55.4*
" 54	12	48	22	46.8
" 55	12	49	37	48.0
" 56	12	50	55	46.1
" 57	12	52	8	49.3
" 58	12	53	18	51.4
" 59	12	54	28	51.4
" 60	12	55	41	48.7
" 61	12	56	52	50.7
" 62	12	58	5	49.3
" 63	12	59	15	51.4
" 65	1	1	57	50.7
" 66	1	2	47	51.4
" 67	1	3	57	51.4
" 68	1	5	5	53.0
" 69	1	6	13	53.0
" 70	1	7	21	53.0
" 71	1	8	21	60.0
" 72	1	9	31	51.4
" 73	1	10	38	53.7
" 74	1	11	45	53.7
" 75	1	12	53	53.0
" 76	1	14	0	53.7
" 77	1	15	37	Slackened speed at 76¾ post
Swindon	1	16	30	Due 1.12

* Slack through Didcot.

About 3½ minutes lost by engine. About ¼ minute lost by slacks.
Running average, 51.7 miles per hour.

It was, however, a general practice with the drivers to drop a few minutes on the run to Swindon, and to make it up again between Swindon and Bath by "rushing" the Wootton Bassett and Box Tunnel banks of 1 in 100. The eight-mile stretch from the 86th post to the 94th post (Chippenham) was usually covered in about 7¼ to 7¾ minutes, or at 62 to 64 miles per hour. The fastest speed at which I ever timed one of these engines was when riding on the foot-plate of engine Lightning, with the up afternoon express from Exeter (generally known as the Zulu), and the four miles down the Wellington bank were covered in 2 minutes 55 seconds, or at an average speed of 82 miles per hour, the load being five 8-wheelers.

Your description on page xiii., and illustration on page vii. of the 9ft. "single" tank engines of the Bristol and Exeter Railway needs a slight correction. Your illustration in Fig. 9 shows these engines as originally designed by Mr. Pearson in 1853, and built in 1854 by Messrs. Rothwell Company, of Bolton, at which time the engines had 9ft. wheels. Four out of the eight engines were afterwards (1868-73) modified, when they were rebuilt with 8ft. 10in. wheels and 18in. by 24in. cylinders (in place of 16½in. cylinders), and in their later state were fully illustrated by you (Vol. lxix., 1890, page 356). The outer bearing to the driving wheels was removed.

These four engines (Great Western Railway Nos. 2001—2004) were altered to tender engines about 1876, after the Bourton accident, and only two of them, Nos. 2001 and 2002, were at work from 1884 to 1890, when they took their turns with the "Gooch" 8ft. singles in the Bristol link. E. L. AHRONS.

Nottingham, December 17th.

GREAT WESTERN RAILWAY 36-TON STEAM BREAKDOWN CRANES.

SIR,—We notice in your Great Western Railway Supplement, dated the 16th December, that you mention "that two 36-ton Stothert and Pitt cranes have recently been purchased by the Great Western Railway Company." We would like to point out, however, that this is not correct, because we had the pleasure of providing one of the cranes in question, and Messrs. Stothert and Pitt the other. Would you, therefore, be good enough to mention this fact in your next issue.

RANSOMES AND RAPIER, LIMITED.

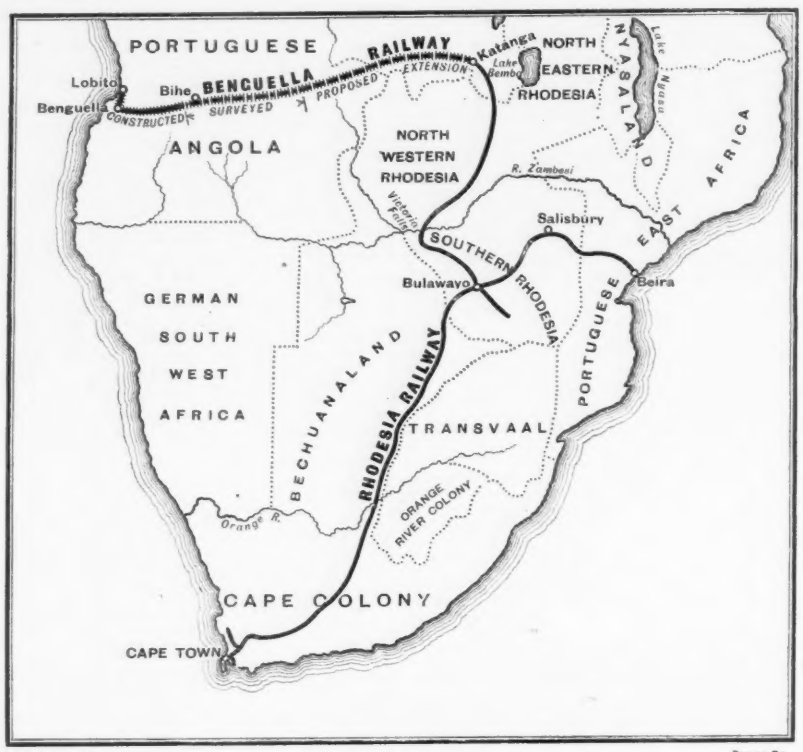
London, December 19th.

THE BENGUELLA RAILWAY.

DURING the last twelve months active progress has been made in the construction and equipment of the Benguella Railway in Portuguese Angola, South-West Africa. The contract was let to Pauling and Co., Limited, of Westminster and Cape Town, by the Benguella Railway Company, in November, 1909, for the construction and equipment of the section of railway from kilometre 198 to kilometre 323—125 kilos., or 77½ miles. This work was completed in October, 1910, six weeks ahead of contract time. Traffic is now running up to railhead at kilometre 323 from Lobito, the company's port.

A contract has been arranged with Pauling and Co. for the construction and equipment of a further section of railway from kilometre 323 to kilometre 360—37 kilos., or 23 miles. The surveys of the railway will be completed up to Mutota—kilometre 900—562 miles from Lobito, by June 30th, 1901. The total distance from Lobito to the Congo frontier is estimated at about 1300 kilos., about 800 miles.

Starting from sea level at Lobito the line reaches a height of 1508 m. (4948ft) at kilometre 323. The gauge of the railway is 3ft. 6in., and to this point the minimum curve is 90 m. radius, with 1 in 40 (compensated) maximum gradient, except for a short length of about 2 kilos., where a "Riggenbach" rack section has been introduced, with a gradient of 1 in 16, to save heavy earthworks.



THE BENGUELLA RAILWAY

The Port of Lobito, which is by nature one of the finest harbours in Africa, is equipped with a substantial timber jetty and wharf capable of taking the largest steamers running to South Africa. The section of the railway from Lobito to kilometre 198 was constructed by Griffiths and Co. (Contractors), Limited, under contract from the Benguella Railway Company. Serious difficulties of water supply have had to be overcome on the section of the line to kilometre 200, but beyond that point there is ample water.

The whole of the works have been carried out under the specification, designs, and supervision of the company's engineers, Sir Douglas Fox and Partners and Sir Charles Metcalfe. Mr. Edward Robins acted as the company's chief resident engineer at Lobito, with Mr. H. F. Varian and Mr. Fitzgerald as his first and second assistants. Mr. Homer has been in charge of the surveys. Mr. Varian also has charge of the maintenance of open lines, with Mr. Schofield as first assistant. Senhor Marianno Machado acts as the company's representative and manager at Lobito. He is a brother of General Sir John Machado, a director of the company at Lisbon. The following firms have supplied rolling stock for the railway to the engineers' specifications, viz.:—Locomotives (adhesion): The North British Locomotive Company, Limited, Kitson and Co., Limited, the Hunslet Engine Company, the Avonside Engine Company, and Hudswell, Clarke and Co. Locomotives (rack): The Maschinenfabrik Esslingen of Stuttgart. Carriages: The Gloucester Railway Carriage and Wagon Company, Limited, the Metropolitan Amalgamated Railway Carriage and Wagon Company, Limited, and the United Electric Car Company, Limited. Wagons: Cravens, Limited, the Metropolitan Amalgamated Railway Carriage and Wagon Company, Limited, and the Blake Boiler and Engineering Company. All the rolling stock is of the latest South African standard, of double-bogie type, with central buffers, and is fitted with both vacuum and hand brakes.

THE SHIPBUILDING LOCK-OUT.

AS was intimated in our last issue, the labour war in the shipbuilding industry of Scotland and the North-East coast of England ended on the 14th, and work was resumed at the shipyards on the next day, but only partially, for it was impossible to find work for all who had been locked out or thrown out of employment as a result of the lock-out. This week nearly all the men have been restarted, and the shipbuilding industry is in almost full swing again after fifteen weeks of nearly total stoppage. Briefly stated, the chief facts in connection with the struggle were:—Lock-out notices posted September 2nd; lock-out began September 3rd; shipyards idle, over 100; men out of work, between 50,000 and 60,000; estimated loss in wages, nearly £1,000,000; estimated loss to employers, fully £150,000; lock-out pay to men by trades unions, £112,500; lock-out ended December 14th. The whole of the shipbuilding industry in the districts named has been dislocated by the dispute, and thirty-five to forty thousand men who had no connection with it were deprived of their employment; in fact, for nearly all the fifteen weeks to which the lock-out extended the shipwrights, carpenters, and all other departments of skilled workers were idle. At least 15,000 skilled artisans and 8000 labourers were thrown out of employment, besides the 15,000 boilermakers in the early part of the struggle, and before the end probably 60,000 men were deprived of their means of earning a livelihood. Ninety-one federated building yards and twenty-four repairing yards were concerned in the dispute, and though the settlement is regarded by the men as a "peace with honour" adjustment, it may be affirmed that they are really no better off at the close than at the beginning of the struggle, the only point gained being that the Employers' Federation will punish any of their members who break the National Agreement entered into at Edinburgh in March, 1909. The employers have secured a pledge that the members of the Boilermakers' Society will be actually punished by their union when they violate the same agreement. The men's union had power, by their own rules, to punish the members when they entered upon hasty and unauthorised strikes, but it was acknowledged by their officials that they did not carry out the rules in this respect, and offenders escaped unpunished, so that the men did just as they liked. It was to put a stop to these sectional stoppages that the lock-out was decreed by the Employers' Federation. It was mainly to prevent such stoppages that the Edinburgh agreement of last year was made, but the boilermakers were the chief, indeed almost the only, men of the eighteen unions which were parties to the agreement that ventured to disregard its provisions, and threw down their tools whenever they did not get their own way.

There are now bright prospects of continued regular operations at the shipyards, plenty of work is waiting at the shipbuilding and ship repairing establishments, and heavy arrears have to be made up. The employers may find some difficulty in overtaking these arrears, for it is stated that a large section of the men have resolved not to work overtime—they seem to resent what they term "undue haste." On the Clyde the amount of work in hand is practically unprecedented, and next year the output of shipping should be the largest on record, exceeding even that remarkable year 1907. There the orders booked include those for twenty battleships, cruisers, and torpedo destroyers, while there are contracts for 200,000 tons of merchant shipping. At the South Durham Steel and Iron Company's West Hartlepool Steel Works, which are mainly engaged in the manufacture of steel ship plates, a number of the men were restarted about the middle of last week, and this week 800 men are employed, while next week No. 3 mill and the cogging mill will be ready, and the full complement of men, numbering about 1200, will be at work. Messrs. Bolckow, Vaughan and Co. had to close their plate mills at the Eston Steel Works during the lock-out, but they are once more in operation.

This week the shipbuilders have offered the boilermakers and other shipyard men the same terms with regard to an advance of wages as have been accepted at the engineering establishments and also by the moulders, namely, an advance of 1s. per week to men rated at 25s. per week and over, and 6d. per week to men rated at 22s. and under 25s.; to piece workers 2½ per cent. advance, these to take effect at once; also a further advance of the same extent to take place in six months, and after that the rates of wages are to remain undisturbed for a period of five years from the date of the second advance, so that industrial peace will be assured for five and a-half years.

INSTITUTION OF POST-OFFICE ELECTRICAL ENGINEERS.

AT a meeting of the Metropolitan Centre of the Institution of Post-office Electrical Engineers held on Monday, the 12th inst., at the Northampton Institute, Clerkenwell, Mr. J. G. Lucas, of the Headquarters Staff, gave a paper dealing with the result of some extensive investigations which had been carried out in practice and under laboratory conditions in connection with the ordinary types of signalling batteries used by the British Post-office and other telephone administrations.

In dealing with the porous pot Leclanché type of cell, Mr. Lucas showed that the text-books were very much out of date on this question, and that modern telephone requirements could be met much more economically by modifying the subdivision of the maganese dioxide and carbon in the porous pots. In the case of even such small current discharge rates as 40 milliampères, the result of the modifications was shown to decrease the total working costs by not less than seven times; whilst at discharge rates higher than 40 milliampères, the decrease in costs was shown to be much greater. The agglomerate form of Leclanché battery, Mr. Lucas pointed out, was an expensive type, and the possible advantages which may be derived by its use were not commensurate with this expense.

In connection with the use of dry cells as at present designed, the investigations went to show that the chief difficulties and expense lay in the fact that for discharges which must necessarily be spread over several months, the full use could not be made of the chemical energy vested in the materials used in these cells owing to the sudden rise after a time in the internal resistance. Details were given of experimental cells, the behaviour of which indicated that the difficulties were not insuperable. As the free ammonia gas evolved from Leclanché cells is found seriously to affect the metal work of telephones and to act deleteriously upon secondary cells, Mr. Lucas gave details of satisfactory experiments which had been conducted with an electrolyte of manganese chloride instead of the usual ammonium chloride solution. He pointed out the practicability of sealing up the battery compartments in connection with cells charged with manganese chloride solution, and the consequent reduction in loss by evaporation as compared with ammonium chloride solutions.

In comparing the costs and efficiencies of the various batteries for subscribers' speaking purposes, Mr. Lucas stated that even experts in determining telephone transmission efficiencies were unable to perceive any loss due to the resistance of the usual two-cell speaking battery rising from .5 ohm to 4 ohms, and that even at 6 ohms internal resistance the loss was only just appreciable to experts. This, he pointed out, had an extremely important bearing upon the question of the most economical type of battery to be used for subscribers' speaking sets, and he gave information relating to a modified type which would apparently result in the total working costs being reduced to half as compared with those of the existing agglomerate battery and nearly to one-third as compared with those of dry cells.

NEW NAVAL WORK FOR THE CLYDE.

IT comes somewhat in the nature of a pat on the back to both combatants—so far, at least, as the Clyde district is concerned—that just when by a majority—which almost deserves to be spelled "unanimity"—the locked-out shipyard workmen have declared for acceptance of the amended working agreement, the Admiralty's very substantial order of an improved Dreadnought battleship should be announced as having been given to Scott's Shipbuilding and Engineering Company, Limited, Greenock. The news, when given out by the firm named, caused the greatest satisfaction, not only in Greenock, but in Glasgow and throughout the Clyde district. This warship is one of two arranged for in the Admiralty's latest programme, the offers for which were invited from leading shipbuilding firms in various British districts some time ago. The new vessel will be considerably heavier and to some extent larger than the battleship Colossus, which is now being fitted out at Greenock by the Scott Company. She is not to be of the cruiser or Lion type, but will be the most formidable and the largest of the battleships known as improved Dreadnoughts.

Although following the custom which the Admiralty rigorously enforce upon their contractors, no specific details are available as to the size and character of the new battleship, there is authority for stating that the displacement will be between 23,000 and 24,000 tons, as against the 20,000 tons displacement of the Colossus. The propulsive machinery of the vessel—which, it should be stated, will also be constructed by the Scott Company—will probably be of not less than 27,000 indicated horse-power. The total cost of the vessel, with armament and full equipment, will probably amount no less than £2,000,000. This important commission no doubt affords testimony to the confidence shown by the Admiralty in Scott's Shipbuilding and Engineering Company, especially seeing that the company has at present on hand, although nearing completion, a Dreadnought battleship and a large depôt ship for submarines. In the Colossus the Scott Company built what was at the time the largest battleship in the British Navy, and it is now being entrusted with the construction of one of the largest of the improved Dreadnought battleships.

The Scott Company, it may be added, is at present one of the busiest yards on the Clyde. Apart from the Colossus, the battleship just ordered, and the submarine depôt ship referred to, it has under construction five large liners for the mercantile navy. These include three steamers for the Holt Line, one for the Booth Line, and one for the Donaldson Line. All these vessels are of a high-class character, elaborately fitted, and will thus afford work for all branches of shipyard artisans.

INSTITUTION OF AUTOMOBILE ENGINEERS.—In connection with the fourth meeting of the session of the Institution of Automobile Engineers, which will be held on January 11th, we are asked to state that it has been found necessary to postpone the reading of Mr. Bircham's paper on "The Development of Engines for Marine Purposes," which was previously announced. A paper will be read instead by Mr. C. E. Larard, of the Northampton Polytechnic Institute, entitled "Castellated Shafts," which will be illustrated by the cinematograph.

THE ECONOMICAL WORKING OF RECIPROCATING MARINE ENGINES AND THEIR AUXILIARIES.*

IN our issue of December 2nd last we gave a lengthy abstract of Mr. D. B. Morison's paper bearing the above title. We give in full below the appendices which accompanied the paper.

APPENDIX A.

Communicated by Professor A. L. MELLANBY, D.S.C., of the Glasgow and West of Scotland Technical College.

The following are the particulars of some experiments conducted upon the steam engine in the laboratory of the Glasgow and West of Scotland Technical College, with the object of ascertaining what effect an increase in vacuum has upon its steam consumption and horse-power:—The engine is a horizontal cross compound, the high-pressure and low-pressure cylinders being 12in. and 21in. diameter respectively, with a stroke of 30in., and in the case of these tests there was no receiver between the high-pressure and low-pressure cylinders. The admission and exhaust valves are of the drop piston type, and during the trials the admission pressures and the points of cut-off in both cylinders were as far as possible kept constant. The revolutions of the engine were also maintained at a constant rate by altering the brake resistance for the different conditions of vacuum. The low speed of revolution, 80 per minute, is accounted for by the fact that the trials here presented were part of another series Had the engine been run at its normal speed, 110 revolutions per minute, the steam consumption per horse-power per hour would have been less. The cylinders are not in any way specially designed for working with a high vacuum, but are of ordinary design suitable for the moderate vacuum usually expected in this type of compound engine.

It will be seen that as the vacuum increases both the steam used per hour and the brake horse-power increase. It is easy to see why the horse-power should increase, but the effect of vacuum upon steam consumption is rather more difficult to understand. With increased vacuum there is a remarkable fall in the pressure, and consequently in the exhaust pressure in the high-pressure cylinder. Due to this fall of pressure there are three separate ways in which the steam per stroke is increased. In the first place the weight of steam enclosed in the high-pressure clearance volume at compression is diminished, and so an extra quantity of fresh steam per stroke is required to make up for this diminution. The difference between the high-pressure steam chest and exhaust pressure is increased, and consequently there is an increased amount of valve leakage. Also the mean temperature of the cylinder walls is lowered and there is more initial condensation. With a triple or quadruple expansion engine the effect upon the

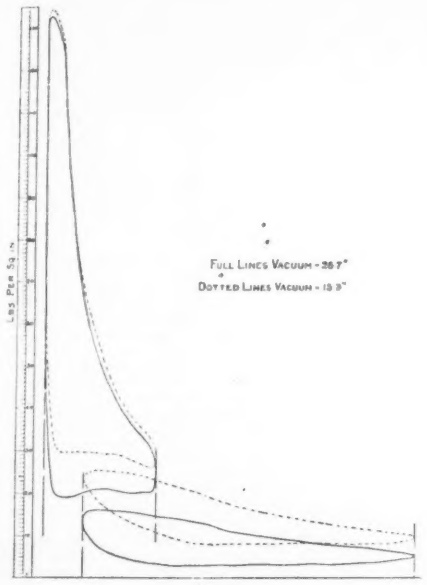


Fig. 1

high-pressure exhaust pressure would be much less marked, and consequently there would be little increase in the steam used per stroke or per hour with increased vacuum. It was determined from the experiments that by raising the vacuum from 20in. to 28in. the steam consumption decreased from 22 lb. to 20.3 lb. per hour per brake horse-power, a diminution of 1.7 lb. per brake horse-power hour over a range of 8in. of mercury.

This is equivalent to a decrease in the steam consumption of 7·8 per cent. over the range mentioned, or an increase in economy at the rate of practically 1 per cent. per inch increase of vacuum in the condenser from 20in. to 28in. vacuum.

The temperature of the air pump discharge has been ignored, but it is obvious from the foregoing that in the case of a marine engine considerable economy may be gained even in a two-stage compound engine by working with a high vacuum and heating the feed by means of the auxiliary exhaust steam which otherwise would go to the condenser direct, and the economy resulting from the application of this system to triple and quadruple engines would, of course, be much greater. It should be noted that the above experiments relate only to the particular engine tested, and the results would not compare with those obtainable from a marine engine specially designed for obtaining the highest economy from high vacuum. The low-pressure cylinder indicator diagrams taken from this engine are shown in Fig. 1.

APPENDIX B.

THE EFFECT OF VACUUM UPON THE STEAM ECONOMY OF TRIPLE-EXPANSION HIGH-SPEED ENGINES.

Communicated by Mr. R. K. MORCOM, M.I.M.E.

(Belliss, Morcom and Co., Limited.)

The observations detailed in the following notes were made during the official steam consumption trials of a triple-expansion high-speed engine. The primary object was to ascertain the extent to which the economical performance of the engine could be influenced by reducing the exhaust pressure. The engine used for the purpose of the trials was one of eight similar sets intended for dynamo driving and designed to develop a normal full load of 1080 brake horse-power when running at 250 revolutions per minute. Forced lubrication was supplied for crank shaft and motion work bearings, the leading dimensions of the engine being as under:—

Diameter of high-pressure cylinder	18½in.
Diameter of intermediate-pressure cylinder	27in.
Diameter of low-pressure cylinder	40in.
Stroke of pistons	20in.

Piston valves throughout.

During the period of the trials the engine was exhausting through a short range into a surface condenser having motor-driven circulating pump and steam-driven Edwards air pump. The consumption of steam at the various vacua was carefully measured by weighing the water discharged by the air pump, in accordance with the method recommended by the Institution of Civil Engineers' Committee on Steam Engine and Boiler Trials.

All the conditions were kept as constant as possible throughout, with the single exception of the degree of vacuum. During each trial indicator diagrams were taken from all cylinders, in order that the mean pressures might be ascertained, as well as for purposes of comparison. Every care was taken in connection with the weighbridge measurements, the apparatus being so located as to permit of one observer weighing the exhaust while keeping the tachometer and dynamometer steel-yard in full view. In these circumstances any variation in either the brake load or the revolutions per minute would at once be detected, so that the figures obtained must correspond very closely to actual values. All the readings and diagrams were taken with the engine developing the full load of 1080 brake horse-power.

Four steam consumption tests were made, and the results are given in the tabulated statement on page 18, from which the relative influence of variation will readily be seen.

The indicator cards reproduced below are photographed from the original diagrams—see Fig. 2.

Preparatory to making the first trial, the dynamometer was adjusted until the steel-yard "floated" at the correct load. The exhaust connections were then examined in order to suppress any possible source of air leakage, the vacuum at the engine being brought up to 27·9in. (Barometer 30in.) When the conditions were constant, the steam consumption was carefully measured, indicator diagrams being taken from all cylinders, and the various pressures and temperatures noted at regular intervals. On the completion of this trial, the vacuum was reduced until the condenser pressure rose to 23·8in. vacuum, when a further steam consumption test was taken, along with diagrams and other data. Additional tests were made at 25·8in. and 21·5in. vacuum.

The comparative figures relating to these trials are given in Table I.

From this statement it will be seen that by raising the condenser vacuum from 21·5in. to 27·9in. the steam consumption was reduced from 14·15 lb. per brake horse-power per hour to 12·55 lb., a saving of 1·60 lb. per brake horse-power hour, or approximately 11·3 per cent. The corresponding increase in vacuum being 6·4in., the steam consumption of this engine per brake horse-power would appear to increase at the rate of, say, 1·77 per cent. for each reduction of 1in. in the condenser vacuum.

The tabulated statement is corrected for differences in degree of superheat.

Referring to the low-pressure cylinder indicator diagrams—see

TABLE I.—*Effect of Vacuum on the Steam Consumption of a 1080 Brake Horse-power Quick-revolution Belliss Triple-expansion Engine.*

These trials were made at a steady load of 1080 brake horse-power and at 250 revolutions per minute, the water being measured at air-pump discharge.

Cylinder diameters, 18½in., 27in., and 40in.; stroke, 20in.

Test number.	1	2	3	4
Steam pressure at engine's stop valve (lb. per square inch gauge)	188	186	188	188
Do. do. at H.P. chest	183	180	185	183
Indicated horse-power—H.P.	451	461	431	416
Do. do. I.P.	366	353	369	390
Do. do. L.P.	312	320	323	343
Do. do. Total	1129	1134	1123	1149
Steam temperature, deg. Fah.	474	455	478	482
Superheat, deg. Fah.	91	73	95	99
Cut-off in H.P. cylinder	.4	—	—	.45
L.P. initial pressure from diagram (lb. gauge)	0.5	—	—	3.5
Vacuum at engine, inches	27.9	26.8	25.8	21.5
Steam consumption, lb. per B.H.P. hour, actual	12.7	13.2	12.83	14.16
Do. do. corrected to 100 deg. Fah. superheat	12.55	12.68	12.74	14.15

APPENDIX C.

Communicated by Messrs. W. ESPLEN AND SONS, Consulting Engineers, 31, James-street, Liverpool.

The following data, obtained from the T.S.S. Indrabarah, owned by Sir Thomas Royden, Bart., and built to our designs, may be of interest. This vessel has just completed her first outward passage to Australia fully loaded. The vessel is of the three shelter deck type of the following dimensions:—

Length between perpendiculars	470ft.
Breadth, external	58ft.
Depth, moulded	43ft. to shelter deck

and has been built by Swan, Hunter, and Wigham Richardson, Limited, at Wallsend-on-Tyne, and engined by Richardsons, Westgarth and Co., at their Hartlepool engine works. Her total displacement at a load draught of 28ft. 10½in. is 17,025 tons. She is insulated for the carriage of cargoes of chilled and frozen meat, and is fitted with a compound duplex C.02 machine capable of dealing with an insulated capacity of 292,380 cubic feet.

Her engines are of the twin-screw triple-expansion type, each having cylinders 22in., 37in., and 62in., with a stroke of 45in., and

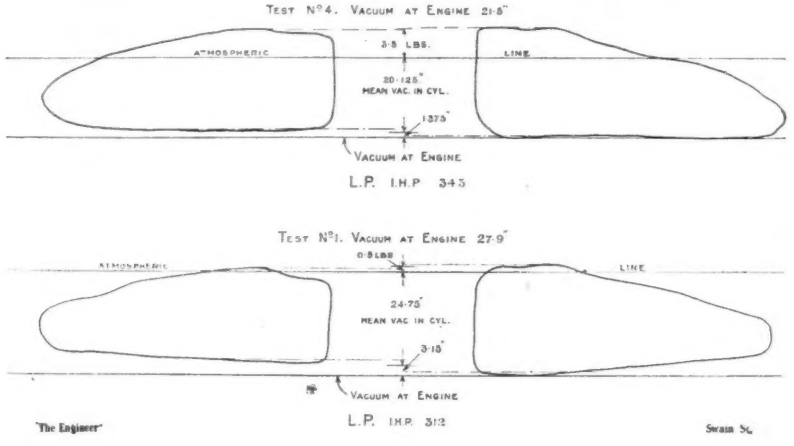


Fig. 2

Fig. 2—and tabulated statement, it will be seen that the vacua given are those corresponding with the condenser pressures obtaining at the time cards were taken. For an increase in condenser vacuum of 6·4in. the low-pressure cylinder power fell from 343 to 312 indicated horse-power, a reduction of 31 indicated horse-power, or, at the rate of, say, 4·85 indicated horse-power per 1in. additional vacuum.

If the engine had no governor the increased vacuum would be productive of (1) higher speed, (2) greater total steam consumption per hour, (3) augmented power output. Usually with expansion governing the power developed by the low-pressure cylinder for a given total load would not increase for a reduction in the terminal pressure, because the earlier cut-off in the high-pressure cylinder would generally more than neutralise any such tendency. In the case of this particular set the shaft governor controls the engine both by throttling the steam and varying the cut-off, to accomplish which the slide valve has inclined ports, and may be rotated automatically so as to vary the lap. As the percentage cut-off in the high-pressure cylinder may be directly read from a suitably divided indicator plate attached to the expansion gear, the cut-offs at high and low vacua were noted, the readings being given in the tabulated statement.

At the low vacuum (21.5in.) the mean cut-off in the high-pressure cylinder was .45; at high vacuum (27.9in.) the cut-off was automatically reduced to .4. As the diminished cut-off would necessarily be accomplished by a closing of the throttle valve (both motions being taken from the one lever) the relative position of the cut-off gear affords interesting and conclusive proof as to the absolute effect of increased temperature range upon the steam consumption of this engine. Even if the weight of steam used had not been ascertained by careful measurement, the position of the cut-off gear and governor valve would have roughly indicated the steam economy consequent upon the higher vacuum. This may be further verified by an inspection of the low-pressure indicator diagrams—see Fig. 2—from which it will be noted that the receiver pressures are very considerably higher at a vacuum of 21.5in. than at 27.9in., an effect consequent upon the relative positions of throttle valve and expansion gear at constant brake load and revolutions per minute. This further explains why the low-pressure power does not necessarily fall off with increased back pressure.

In making the trials outlined in the foregoing every care was exercised with a view to accurate determination of the economy in steam due to higher vacuum. The brake used was a Froude water dynamometer, and as the engine ran at full load throughout, the brake conditions were such as to be constant in a degree quite exceptional in commercial engine testing. Two Crosby indicators were employed, the cocks being screwed directly into the top and bottom ends of the cylinder. These instruments were carefully cleaned and oiled, all the diagrams being taken by the same observer. The drums were driven from stout piano wires kept in tension by a stiff spiral spring. The vacuum was measured on a mercury column which was checked against an absolute pressure barometer.

are capable of indicating 5000 I.H.P. at 95 revolutions per minute; there are four single-ended boilers fitted with forced draught having a total heating surface of 11,192 square feet, and working at 200 lb. pressure per square inch. The design of these engines is based on the principle that the most economical and efficient results will be obtained by the adoption of such cylinders as will enable the engines to be run at their full designed power without linking up and at a high piston speed; with the Contraflo system of high vacuum and temperature regulation in combination with cylinders provided with suitable proportions of steam and exhaust passages.

The installation of engine-room auxiliaries is unusually large; this comprises independent feed pumps, feed filter, feed heater, evaporator, distiller, dynamo, sanitary pump, fresh water pump, two centrifugal pumps, two fan engines, ballast pump, refrigeration circulating pump, telemotor steam steering gear, as well as C.02 machine, which has cylinders 16in. and 29in. diameter by 21in. stroke, all of which are in daily use. The propellers are of bronze, and of the solid type.

On trials the vessel attained a speed of 14 knots on a six hours run at a draught of 18ft. mean and a displacement of 10,209 tons. The indicated horse-power was 4850, and gives an Admiralty coefficient of 272, which is remarkably high for a vessel of this type. In considering the result from the point of view of economical consumption for the speed obtained, it must be borne in mind that the model to which the ship was built has proved to be particularly good. On the first outward passage the vessel attained a mean speed from London to Melbourne of 12.46 knots on an average draught of 26ft. 3in., or a displacement of 15,300 tons, and an indicated horse-power of 4600 at mean revolutions 85.2, the Admiralty coefficient being 260. The best day's run was 325 knots in twenty-three and a-half hours, or 13.8 knots per hour, the Admiralty coefficient being 350.

The coal supplied was North Country "Mickley" unscreened, giving about 11 per cent. ash, and the total consumption per twenty-four hours, including all auxiliaries, was 66.33 tons, or about 1.34 lb. per indicated horse-power per hour of North Country coal, equal to 1.23 of best Welsh coal, a result which is, in our opinion, very remarkable, having regard to the large number of auxiliary engines taking steam from the main boilers, and which, if deducted, would bring the rate of consumption per indicated horse-power for the main engines only to an exceedingly low figure. The most striking feature of the indicator cards is the high vacuum shown in the cylinder, the exhaust line being within about 2in. of the condenser vacuum up to a condenser vacuum of at least 28in.

The low-pressure ports and exhaust passages were carefully proportioned to ensure a low resistance by giving a clear and

* ERRATUM.—In our reprint of the above paper in our issue of December 2nd, page 606, 2nd column, line 84, for "brass tubular pockets" read "steel tubular pockets."

unrestricted passage for steam without excessive clearance or pockets for its lodgment.

In conclusion, we would state that we attribute the economical running of the above engines to the following causes:—(1) High vacuum and ability to maintain it in high temperature sea-water; (2) utilising the exhaust steam from the auxiliaries to heat the feed water up to the maximum temperature at which it can be dealt with by the feed pumps; (3) the provision of such a capacity of cylinders and boilers as will enable the boilers to provide ample steam at full power without being unduly pressed, and as will enable the engines to run at their full designed power and mean pressure without being linked up, as is common in marine practice; (4) comparatively high piston speed.

The above results were obtained, not under the artificial conditions of a trial, but under sea steaming condition, and during a first voyage, which makes them all the more worthy of notice.

APPENDIX D.

Quadruple-expansion Engines and High Vacuum.

Communicated by Mr. R. J. Quelch, M. Inst. C.E. (Messrs. Lawther, Latta and Co.).

The advantageous extension of temperature range being a leading characteristic of the quadruple engine, the lower limit of temperature is obviously a most important factor, especially when it is remembered that the upper limit of temperature remains constant at constant boiler pressure. Therefore the question of vacuum arises, since, other things being equal, it is upon the vacuum that the temperature range will depend. Quadruple machinery designed to work normally at a high ratio of expansion will necessarily give a relatively small mean pressure, so that in such circumstances successful operation may be readily prejudiced by imperfect vacuum. If the quadruple be worked at the highest vacuum to which the engine will respond, then there ensues a low condenser temperature. Such need not, however, produce a low temperature of feed, if the auxiliary exhausts are condensed by the air pump discharge water.

Table II.—*Vacuum and Temperature Readings taken by the Chief Engineer of the s.s. Camerata. On Voyage from Tunis to Rotterdam, September,* 1910.

Date.	Vacuum. Inches.	Temperature at top of condenser. Deg. Fah.	Circulating water. Inlet Deg. Fah.	Temperature on suction side of feed pump.	Temperature on discharge side of feed pump.
September 21	27½	110	74	142	239
,, 21	27½	110	74	143	239
,, 22	27½	110	74	143	240
,, 22	27½	110	74	143	240
,, 23	27½	111	75	143	240
,, 23	27½	110	74	142	240
,, 24	27½	110	71	141	240
,, 24	27½	109	68	142	240
,, 25	27½	109	68	143	239
,, 25	27½	110	67	142	239
,, 26	27½	109	66	141	239
,, 26	27½	109	66	141	239
,, 27	27½	108	63	141	238
,, 27	27½	108	61	141	238
,, 28	27½	108	62	142	238
,, 28	27½	108	63	142	239
,, 29	27½	108	62	141	238
,, 29	27½	107	61	140	238
,, 30	27½	107	60	140	238
,, 30	27½	106	59	140	238

In order that the most economical results may be obtained from quadruple and other multiple-expansion marine engines, provision ought to be made for the maintenance of the requisite vacuum throughout the voyage, particularly at high expansion ratios. In this connection engineers are apt to forget that, so far as temperature range is concerned, variation in boiler pressure is of much less consequence than variation in exhaust pressure. It is uneconomical to work quadruple expansion engines at low vacuum; moreover, the means of condensation ought to be such that the exhaust pressure may be kept constant throughout tropical voyages. Generally, therefore, the maintenance of boiler pressure and of vacuum should be regarded as equally vital to successful practice in quadruple expansion engines.

It may be in point to refer to the quadruple engines of the Anglo-Patagonian, built to my designs and specification by the North-Eastern Marine Engineering Company, Limited. These engines are 24in., 34½in., 49in., 71in. by 48in. stroke. The boiler pressure is 220 lb. per square inch. The condenser is of the Contraflo type, with temperature regulator, and the boiler feed pumps deliver the feed water through the tubes of a surface feed heater, into which all available auxiliaries exhaust. On the occasion of the official loaded trials—August 17th, 1910—the total temperature range within the cylinders actually reached 263 deg. Fah., the higher limit of pressure being, say, 225 lb. absolute, and the lower limit 2.16 lb. absolute. This is a very unusual result, particularly as the lower limit of temperature corresponds with the mean back pressure in the low-pressure cylinder, and not

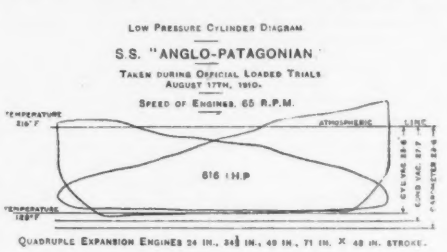

Low Pressure Cylinder Diagram
S.S. "ANGLO-PATAGONIAN"
Taken during Official Loaded Trials August 17th, 1910.
Speed of Engines, 65 R.P.M.
TEMPERATURE 216° F
ATMOSPHERIC LINE
616 I.H.P
TEMPERATURE 189° F
CYLINDERS 24" 34½" 49" 71" DIA. STROKE 48"
BACK PRESSURE
Quadruple Expansion Engines 24 in., 34½ in., 49 in., 71 in. × 48 in. stroke.
Effective area of low pressure piston 5,040 sq. in.

Fig. 3

with the absolute condenser pressure. A low-pressure cylinder diagram taken during these trials is reproduced below. See Fig. 3. The dimensions of the Anglo-Patagonian are:—Length between perpendiculars, 403ft.; moulded breadth, 52ft.; moulded depth, 29ft. 1½in. The official loaded trials were taken with some 8550 tons of coal bunkers and stores on board, the vessel displacing about 12,120 tons. At this displacement the mean speed was 10.35 knots. It ought, perhaps, to be added that the order of the results will be conditioned by the extent to which high condenser vacuum is maintained concurrently with high feed temperature.

APPENDIX E.

Triple-expansion Engines of the Djerissa Class (La Tunissienne Steam Navigation Company, Limited).

Communicated by Mr. A. Walker, M.I.N.A. (of Messrs. F. Strick and Co.).

There are three ships in the Djerissa class—the Djerissa, Camerata, and Boukadra, each of the vessels having a deadweight carrying capacity of about 6200 tons on a displacement of approximately 8800 tons. The length between perpendiculars is 350ft., the extreme breadth 50ft., and the depth moulded 25ft. 11½in. The engines are triple-expansion 24in., 38in., and 64in. by 42in. stroke, with two boilers 13ft. 6in. mean diameter by 11ft. 6in. long. The pressure is 180 lb., and the boilers work under forced draught. The engineers are instructed to maintain high condenser vacuum, and heat the feed by means of drainage water and vapour from the various cylinder and receiver drains, evaporator and feed heater coil drains, &c. It is found that, notwithstanding the comparatively high vacuum, the temperature of the hotwell water may be raised to the limit permitted by the feed pumps, which are of the plain ram type driven from the main engines.

Service records from each of these steamers show that the vacuum within the low-pressure cylinder is from 25in. to 26in., the condenser vacuum averaging from 27in. to 27½in. when the steamers are on their regular Mediterranean service in sea water to there being means available whereby water from the bottom of the boilers may be circulated through the feed heater coils instead of steam.

A schedule of temperatures taken on the Camerata is also attached, together with a recent low-pressure cylinder diagram from the same steamer—see Fig. 4. The average power maintained by the three ships is about 1080 indicated horse-power, so that the engines are working at considerably less than the normal full load corresponding with the given dimensions. In these circumstances the system followed is to fully open all the boiler and engine stop valves, running with maximum pressure in the high-pressure receiver and reduced cut-off. The readings tabulated were, of course, taken during the respective watches, and are subject to the margin of error which is normal to determinations made at sea. It might be added that in these vessels the air and circulating pumps, as well as the boiler feed pumps, are all driven by levers from the low-pressure crosshead.

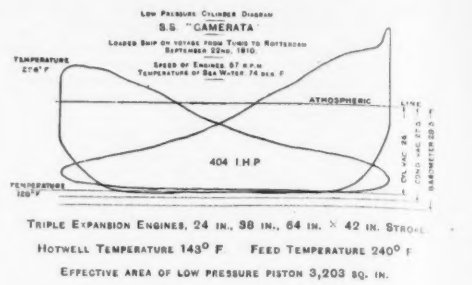

Low Pressure Cylinder Diagram
S.S. "CAMERATA"
Loaded Ship on voyage from Tunis to Rotterdam September 22nd, 1910.
Speed of Engines, 67 R.P.M.
Temperature of Sea Water, 74 deg. F
TEMPERATURE 270° F
ATMOSPHERIC LINE
404 I.H.P
TEMPERATURE 120° F
CYLINDERS 24" 38" 64" DIA. STROKE 42" BAROMETER 29.5
Triple Expansion Engines, 24 in., 38 in., 64 in. × 42 in. Stroke
Hotwell Temperature 143° F Feed Temperature 240° F
Effective area of low pressure piston 3,203 sq. in.

Fig. 4

AMERICAN NOTES.

(From our own Correspondent.)

New York, December 14th.

The only vigorous branch of the steel industry at the present time is in tin-plate. Heavy buying is in progress for the first half of 1911. The Steel Corporation has increased its production to 70 per cent. of capacity. The steel plate makers have been encouraged by a large order for plates for new freighters on the Lakes, and for numerous industrial extensions. One order amounts to 10,000 tons for boats on the Ohio River. This order was taken by the American Bridge Company. None of this material will be wanted for a few months. Buyers took advantage of the present low prices to secure material when they needed it. Pipe makers are taking orders for no later than delivery at 60 days ahead at present prices. The estimated stocks of pig iron are 1,700,000 tons as a minimum, as against 1,100,000 tons at the opening of the year. The reason for this is that forward buying has been practically discontinued. Some disappointment has been expressed over the refusal of the great steel interests to shade prices down, but this determination cannot be shaken. Prices will remain stationary through 1911, apart from trifling fluctuation in some minor lines. There will be no changes in tariff duties for perhaps eighteen months, as the present session of Congress expires March 4th, and the new democratic Congress does not come in until December next year. A tariff commission, which will have power to recommend, will be created, and its recommendations will be the subject for legislation. No change has occurred in copper and larger consumers are supplied until about February 1st. Exports since December 1st were 6408 tons. All indications point to a steady market. To-day's tin arrivals were 500 tons, amounting to 1518 tons. The lead market is quiet and prices steady.

Table III.—*Abstract from the Logs of the s.s. Camerata. Voyage from Newport to Oran. Mean Power throughout the Voyage* 1080 *I.H.P.*

Date.	Pressure of steam.	Inches of vacuum.	Temperature. Feed to boilers.	Temperature. Sea.	Revolutions per minute.	Coal. Tons cwt.	Coal. Description.	Distance. Propeller.	Distance. Observed.	Average speed per hour.	Slip, per cent.	Buckets of ashes per day.
1910.												
October 15	175	27½	212	61	57	15 10	Welsh	173	166	8.9	4	75
,, 16	175	27½	210	61	56	17 0	,,	219	158	6.54*	28	118
,, 17	175	27½	211.5	62.3	57	17 0	,,	223	194	8.0	13	123
,, 18	175	27½	211.3	63	57	17 10	Newcastle	223	225	9.3	nil	119
,, 19	175	27½	211.6	65	57	17 0	Welsh	222	220	9.2	1	120
,, 20	175	27½	211	67.3	57	17 0	,,	220	230	9.7	nil	116
,, 21	175	27½	211	69.6	57	15 10	,,	186	182	9.1	2	78

* Strong wind and high sea, shipping water.

Coal used was of a fairly good steaming quality, rather fast burning and dirty. About 80 per cent. small. Clinker easily removed from bars and did not seem destructive to bars. The small cakes very well and does not run through the bars. Ash and dirt about 21 per cent.

Table IV.—*Abstract from the Logs of the s.s. Boukadra. Voyage from Barry Dock to Naples. Mean Power throughout the Voyage* 1085 *I.H.P.*

September 13	180	28	224	63	59	9 10	Welsh	128	123	9.18	4	34
,, 14	180	27	218	64	59	17 0	,,	231	225	9.32	2.5	117
,, 15	180	27	218	64	59	17 0	,,	231	219	9.08	5	101
,, 16	180	27	222	66	59	17 0	,,	230	214	8.91	7	95
,, 17	180	27	222	71	59	17 0	,,	229	219	8.75	8.7	75
,, 18	180	27	218	71	59	17 0	,,	227	219	9.24	3.5	66
,, 19	180	27	215	75	59	17 0	,,	227	204	8.59	10	78
,, 20	180	27	218	76	59	17 0	,,	227	195	8.21	14	76
,, 21	180	27	216	72	59	17 0	,,	227	214	9.02	5.7	80
,, 22	180	27	220	76	59	17 0	,,	227	203	8.55	10.5	79
,, P.M.	180	27	220	76	59	7 15	,,	103	93	8.58	9	28

The coal used was Welsh through of medium quality. Good steaming and slow burning. About 70 per cent. small made a heavy clinker which sticks to the fire bridges and is difficult to remove. The small cakes. Ash and clinker, 17 per cent.

Table V.—*Abstract of Logs of the s.s. Djerissa. Voyage from Dunston-on-Tyne to Barcelona. Mean Power throughout the Voyage* 1060 *I.H.P.*

August 21	170	27½	212	60	58	8 10	Newcastle	51	53	8.4	nil	20
,, 22	180	27½	212	60	61	20 10	,,	236	220	9.1	7	114
,, 23	180	27½	224	63	58	18 0	,,	228	192	7.9	15	116
,, 24	180	27½	223	62	58	18 0	,,	227	182	7.5	19	116
,, 25	180	27½	224	65	58	17 10	,,	226	201	8.3	11	107
,, 26	180	27½	224	67	58	17 0	,,	225	173	7.2	23	110
,, 27	180	27½	226	68	58	17 0	,,	225	217	9.0	3.5	108
,, 28	180	27½	228	67	58	17 0	,,	223	218	9.1	2.2	107
,, 29	180	27½	236	74	58	17 0	,,	223	214	9.0	3.8	107
,, 30	180	27½	138	77	58	17 0	,,	223	213	9.0	4.5	110
,, 31	180	27½	138	77	58	12 5	,,	179	159	8.6	8.0	81

The coal used was Newcastle, quick burning, with 80 to 85 per cent. small. A good deal runs through the bars, which helps to form the large percentage of ash.

temperatures up to 77 deg. The condensers (Contraflo type) have temperature regulators, and the hotwell water is passed through an air-discharging surface feed heater, so that in addition to being de-aërated the feed water enters the boilers at a temperature of from 215 to 240 deg. Fah. The arrangements are carried out with a view to providing the utmost simplicity, thereby minimising the demand on the labour available. Representative log abstracts are reproduced in Tables III., IV., and V., from which the general performance of each steamer may be estimated. Variation in the feed temperature as between either of the ships is due

Association of Mining Electrical Engineers.—A general meeting of the West of Scotland branch of the Association of Mining Electrical Engineers was held on Friday, 16th inst., in the Technical College, Glasgow. Mr. Alexander Anderson (president) submitted, on behalf of the Committee which had been appointed to inquire into the matter, the syllabus which the branch should put forward to the Council as a provisional scheme so as to form the basis of examinations for certificated membership. The recommendations, briefly outlined, were to the effect (1) that the scope of the examination be limited to the theory and practice of electrical engineering, and should not include special mining knowledge, excepting, of course, a thorough acquaintance with the special rules for the use of electricity in mines; (2) that the examinations be graded, and that there be only two grades for the present; (3) that no candidate under the age of twenty-one years shall sit for the second-class and no candidate under twenty-three years of age for the first-class certificate. Further, candidates shall not be admitted to an examination unless they can show that they have served three years as an apprentice, improver, or journeyman in the electrical and mechanical department of some electrical engineering undertaking, and two years as a practical electrical engineer or electrician in mining work. Under certain conditions alternative training may be accepted. (4) That the examinations shall consist of written and oral tests in theoretical and practical work, with a practical examination in installation, testing, and repair work; and (5) that examiners for the practical and oral examination shall be selected from candidates nominated by the local Council in the district.

Gold Mining in Scotland.—From time to time we hear that gold has been found in Scotland, and that sanguine hopes are being expressed as to the carrying on as a commercial success the recovery of the precious metal. It is, of course, undisputed that gold does exist in Scotland, but whether it will ever be discovered in really workable quantities is another matter. In the days of the later Scottish kings gold mining is reported to have been a thriving industry in the Leadhills district of Lanarkshire, and, we believe, certain coins of the realm were actually struck from this native gold. But the supply, chiefly obtained from the beds of rivers, has long since been practically worked out. A few years ago it was reported that gold had been found in workable quantities in Argyllshire. Operations were commenced, a few grains of gold were produced, and then the project was abandoned, as usual. Fifty years ago Kildonan, near the east coast of Sutherlandshire, witnessed a "gold rush," but the work was soon stopped, as the shooting tenants in the neighbourhood complained of the number of undesirable characters attracted to the place by the gold mining operations. About fifteen years ago a second attempt was made to work the gold at Kildonan, but geologists reported unsatisfactorily, although certain experienced miners held otherwise, and the work was again stopped. It is now reported that the Duke of Sutherland is prepared to allow a third trial at the Kildonan goldfields, and we believe hopes are being entertained that this time success will reward the efforts of the speculators. In whichever way the work goes the neighbouring village of Helmsdale will be sure to benefit, and the inhabitants are already congratulating themselves on the prospect of a revival of that prosperity which has so sadly deserted them during recent years on account of the decline in the fishing industry.

THE IRON, COAL, AND GENERAL TRADES OF BIRMINGHAM, WOLVERHAMPTON, AND OTHER DISTRICTS.

(From our own Correspondent.)

The Approaching Holidays.

THE past week has been a busy one at the works, getting orders out of hand before the temporary cessation of activity in connection with the Christmas holidays. Great satisfaction is expressed at the settlement of the boilermakers' strike, the good influence of which will be felt directly and indirectly in the Midlands to a considerable extent. There is very little new business being transacted, as may be supposed at this period of the year, but the general position commercially may be said to remain about the same as a week ago, and without any lowering of tone. Indeed, if anything, a more cheerful and confident spirit appears to prevail, and although the year is closing quietly as regards new transactions, yet 1911 is looked forward to as being likely to be a time of considerable activity.

Pig Iron.

The direction of values in pig iron is upward, and for forward deliveries sellers are asking a considerable advance upon current rates. As to terms for deliveries up to the end of March, there was a fair inquiry on 'Change to-day (Thursday) in Birmingham, and the tone generally was firm, with prospects for the early future satisfactory. Smelters were not anxious to enter into sales at present prices, the high cost of fuel being one of the reasons for this attitude. Staffordshire common forge pig iron was quoted 48s. 6d., part-mine 51s. to 52s., best all-mine forge 85s., foundry 90s., and cold blast 115s. There was a fair inquiry for Midland descriptions, Northamptons being quoted 49s. 6d. to 50s. 6d., Derbyshire 51s. 6d. to 52s. 6d., North Staffordshire forge 50s. to 51s., and best 58s. to 59s.

The Manufactured Iron Trade.

Makers of common bar iron are somewhat more cheerfully inclined, though the work coming to hand is not being materially augmented. There has, however, been a moderate inquiry for deliveries over next quarter, and if manufacturers were content to do forward business at the current figure at about £6 2s. 6d., they might be able to book a considerable amount of work even before Christmas. This course, however, they very naturally are not at all inclined to pursue, considering it very probable that the amount they will have to pay for pig iron and other materials will before long be largely increased. Marked bars are quoted £8, and more orders are expected soon from the chain and cable makers, who are sure to benefit considerably by the termination of the shipbuilding dispute. There is a fairly good demand still for galvanised sheets chiefly for abroad, but values seem to have weakened a little recently, although the general quotation to-day was £11 5s. f.o.b. Liverpool, yet it was understood that some makers were willing to do business at the level £11. A moderate output of black sheets is being made, for which quotations continue:—Singles, £7 10s. to £7 12s. 6d.; doubles, £7 15s. to £7 17s. 6d.; trebles, £8 5s. A quiet trade is being done in gas strip, which is quoted £6 10s. to £6 12s. 6d. Production is fair in material for nail, screw and rivet manufacture, and quotations continue:—Slit nail rods £7 5s., and rivet iron £6 15s. to £7.

The Steel Trade.

There is a very good tone in steel, and it is felt that the large accumulation of work on the Clyde and the Tees is bound to give a great stimulus to the demand; in fact, the outlook may be said to be bright, and a period of activity is looked for by makers both of raw steel and also of engineering descriptions. Quotations remain as follows:—Bessemer sheet bars, £5; Siemens sheet bars, £5 2s. 6d.; angles, £6 12s. 6d. to £6 15s.; girder plates, £7 2s. 6d. to £7 5s.; ship plates, £7 to £7 10s.; and joists, £6 10s.

Carbon and Iron.

At Dudley, on the 17th inst., there was held a meeting of the Staffordshire Iron and Steel Institute (Mr. Walter Macfarlane, president, in the chair), when a paper was read by Mr. W. H. Hatfield, B.Met. (Sheffield), on "Carbon and Iron," with special reference to the precipitation of free carbon in pig and cast irons. The author said his experiments supported the theory that the precipitation of the free carbon was due to the fact that the structurally free carbide, when submitted to a high temperature, under certain conditions, dissociates into iron and carbon. If the carbon, however, be dissolved in the iron it would seem that the material might be subjected to much higher temperatures than those of the danger zone without precipitation taking place. Primarily, the iron contained the carbide in molten solution until at normal temperatures it merely existed in mechanical mixture in the iron, unless conditions were such as to bring about its dissociation. The free carbon, when observed, was found to occur in one of two varieties, graphite or annealing carbon, the former being found in pig irons or grey and mottled cast iron, and the latter in heat-treated white irons. The graphite found in pig and cast iron was now conclusively proved to be produced during and immediately after the solidification of the iron, and its distinctive form was most probably due to the influence of the primary crystallisation upon the newly precipitated carbon. The fact that silicon materially affected the condition of the carbon in cast iron was shown systematically in an original paper in 1886 by Professor Turner, who found that by gradually increasing the silicon content from ·45 per cent. to 1·95 per cent. he progressively increased the percentage of free graphite carbon. Professor Turner's pioneer experiments had had a very material effect upon foundry practice, and had done much to bring about modern scientific control.

NOTES FROM LANCASHIRE.

(From our own Correspondents.)

MANCHESTER, Thursday.

Pig Iron Firm.

THERE appears to be little doubt, judging from the feeling on the Manchester Iron Exchange on Tuesday, that we are on the eve of better things in pig iron. Holders generally quoted higher prices and were not inclined to sell for far forward delivery. There was little Lincolnshire on offer, and hematite and one or two other sorts were 6d. to 1s. per ton higher.

Finished Iron and Steel.

There was no change in finished iron, although the feeling was steady. In steel, plates were higher. Copper and lead: There was practically no change to note in manufactured stuff.

Tin.

English ingots dearer.

Quotations.

Lincolnshire, No. 3 foundry, quoted 54s.; Derbyshire, 55s.; Staffordshire, 54s.; Northamptonshire, 56s. 3d. to 56s. 6d.; Middlesbrough, open brands, 58s. 7d.; January-March, 59s. 4d. Scotch: Gartsherrie 62s. 9d.; Glengarnock, 61s. 6d.; Eglinton, 60s. 9d., delivered Manchester. West Coast hematite, 68s.; East Coast ditto, 65s. 6d. to 67s. 6d., both f.o.t., according to delivery. Delivered Heysham: Gartsherrie, 60s. 9d.; Glengarnock, 59s. 6d.; Eglinton, 58s. 9d. Delivered Preston: Gartsherrie, 61s. 9d.; Eglinton, 59s. 9d.; Glengarnock, 60s. 6d. Finished iron: Bars, £6 15s.; hoops, £7 7s. 6d.; sheets, £8 to £8 2s. 6d. Steel: Bars, £7; Lancashire hoops, £7 7s. 6d.; Staffordshire ditto, £7 7s. 6d.; sheets, £8 to £8 5s.; boiler plates, £7 17s. 6d.; plates for tank, girder, and bridge work, £7 5s.; English billets, £5 5s. to £5 10s.; foreign ditto, £4 15s. to £4 17s. 6d.; cold drawn steel, £9 5s. to £9 10s. Copper Sheets, £71; tough ingot, £61 to £61 10s.; best selected, £61 to £61 10s. per ton; copper tubes, 8½d.; brass tubes, 7d. to 7½d.; condenser, 8d. to 8½d.; rolled brass, 6½d.; brass wire, 6¾d.; brass turning rods, 6¾d.; yellow metal, 6¼d. to 6½d. per lb. Sheet lead, £16 5s. to £16 10s. per ton. English tin ingots, £176 per ton.

The Lancashire Coal Trade.

The attendance on the Manchester Coal Exchange on Tuesday was very good, demand in most departments having been stimulated to some extent on the near approach of the Christmas holidays. House coal was in strong demand for best sorts, but medium and common qualities were in quiet request. Very best was almost unobtainable for immediate delivery. Slack was also in good request for best sorts, and steam coal generally ruled steady. On shipping account there was little change to note, but the "tips" at Partington are still kept very busy, especially for bunkering account.

BARROW-IN-FURNESS, Thursday.

Hematites.

The condition of the hematite pig iron trade is firmer than it has been for some weeks. The termination of the shipbuilding lock-out has put quite a different face upon the position, and now there is every reason to expect that we are in for a much better spell of trade than has prevailed for some time back. There has been a steady demand for iron from general sources and this is increasing on the part of steelmakers. Locally steelmakers are taking good supplies of iron, and this is a state of affiairs that will continue, and there is every probability that makers will have to increase their output The make of iron was considerably cut down a few weeks ago so far as Cumberland is concerned, several furnaces going out of blast. At most of the works there are reserves in the way of furnaces that can be put to work in a very short time. Prices are firmer with makers quoting 67s. per ton net f.o.b. for parcels of mixed numbers of Bessemer iron. Warrants are higher in price at 65s. 9d. per ton net cash, at which price business has been done. Transactions have also been noted at 66s. 10½d. per ton at three months. The stores of warrant iron are well held, and represent in the aggregate 34,073 tons.

Iron Ore.

The iron ore trade right through the district is actively employed. Locally the demand for ore is steady, but, in addition, raisers are doing a good business from outside sources, both for ordinary and best qualities of ore. Prices are firm, with good average qualities at 12s. to 16s. per ton, whilst the highest qualities of Hodbarrow ores are quoted at 21s. per ton net at mines. The importations of Spanish ore into Barrow last week were rather larger. Two big steamers discharged over 8000 tons at the Ramsden Dock. The value of this class of ore is returned at 12s. to 21s. per ton, delivered to West Coast works. Most makers held good stocks of this ore, but with lessened deliveries these stores have been cut into.

Steel.

The steel trade remains without change. Most of the activity is centred in steel rails. The general demand for rails is steady without being over brisk, and the mills at Barrow and also in West Cumberland are pretty well employed on orders for home and colonial buyers. The price of heavy sections of rails remains unchanged at £5 7s. 6d. to £5 10s. per ton. For other descriptions there is only a moderate request. Light rails are at £6 5s. per ton, and heavy sections of tram rails are at £8 10s. per ton. For steel shipbuilding material there is an increased demand, not only on local account, but from general home sources. Nothing is, however, coming to Barrow in this respect, and the plate mills are still standing idle. Tin bars represent a fair home business.

Shipbuilding and Engineering.

These trades are busy again, and there is every prospect of a brisk state of affairs for some time to come. At the Barrow shipyard many good contracts are held, representing a big tonnage, and every department has its hands pretty full. With contracts having a time limit the work will be hustled along.

Shipments.

The shipments of iron last week from West Coast ports represented 5639 tons and steel 4656, a combined total of 10,295 tons, and an increase of 894 tons. The shipments this year stand now at 666,355 tons, and, compared with 601,129 tons in the corresponding period of last year an increase of 65,226 tons.

Fuel.

For coal there is a steady demand throughout this district, and good qualities of steam coal are quoted at 12s. to 16s. per ton delivered. Coke is in fairly good demand at 21s. 9d. per ton delivered from East Coast ovens to West Coast works.

THE SHEFFIELD DISTRICT.

(From our own Correspondent.)

General Conditions.

LITTLE alteration can be reported in the general condition of business in the coal, iron, and steel trades. Inquiries keep up fairly well, but in view of the holidays and stocktaking, together with the overhaul and repair of machinery, not much fresh business has been put through. At the same time the tone continues confident. Apart from specialities, which are in this district, of course, a most important line of trade with all the large steel works, there are few considerable orders on the books. The week has been a busy one in clearing off supplies preparatory to the holiday stoppage, which, as a general rule, will last for about a week. Many special departments will, however, be kept running without intermission. Despite the approaching end of the year, buying continues in the pig iron trade, and evidently consumers are anxious to secure supplies to lower their probable wants next year.

The Coal Trade.

The coal market is still "marking time" more or less, for no definite news is available regarding the railway coal contracts, the result of which has an important bearing on the values at which shipping and other contracts can be subsequently fixed up. The railway companies having refused to accept the colliery tenders at 9s. per ton, the members of the South Yorkshire Association have now reduced their offers to 8s. 9d. per ton, or a reduction of 6d. per ton on last year's contract rates. At the time of writing, the decision, if any, of the railway companies is not known. A scarcity of wagons, chiefly owing to the excessive tonnage hung up at the shipping ports awaiting dispatch, has been felt to an increasing extent, and, as already noted, is affecting outputs. Current prices for steam fuel are steadier, and there is not the forced selling in evidence that was the case recently. Extra supplies are going forward for industrial consumption, in view of the holidays and the probable dislocation of traffic. Manufacturers are renewing contracts up to the end of June next at reductions

Gas Coal, Slacks and Coke.

The very firm market which we have noted for slacks for some time past still obtains, and it has been practically impossible to buy best slacks on the open market for prompt delivery. Some collieries are behind-hand with deliveries on contracts. In most cases where orders are being accepted no promise is made with regard to deliveries. Prices are nominally unchanged, but if collieries had any supplies to offer they could readily obtain advances. Gas fuel is leaving the pits in large quantities, with gas nuts in improved demand for shipment, and more spot business is doing with inland works. Coke is very firm and difficult to procure. Quotations at the pits:—Best washed smalls, 5s. 6d. to 6s.; best hard slacks, 5s. 6d. to 5s. 9d.; seconds, 3s. 9d. to 4s. 3d. Coke, 12s. 6d. to 13s. for best washed, and 11s. to 12s. for unwashed per ton at the ovens.

House Coal.

No great improvement is noticeable in house coal, which remains quietly steady. The dearth of wagons and the smaller outputs are helping to make the market firmer. On the other hand, the milder weather has prevented any general rise in prices which remain officially unchanged.

Pig Iron Market.

With business practically over for the year, the pig iron market holds up very satisfactorily. Of course, prices for common pig iron produced in Lincolnshire and Derbyshire are about at the lowest of the year, but a good tonnage of metal has been sold, and makers are looking forward with confidence for better prices next year. Hematite is very strong, with ordinary mixed numbers quoted at 1s. to 1s. 6d. higher, West Coast qualities being the firmer market of the two. A large quantity of this iron has been booked of late for delivery in this district, the close of the shipbuilding dispute making consumers apprehensive of a further rise in values. Quotations:—Best brands of hematite remain at 79s. to 80s. West Coast, and 74s. to 75s. East Coast. Other quotations are:—Lincolnshire, No. 3 foundry, 50s. 6d.; ditto, No. 4 foundry, No. 4 forge, mottled, and white, 49s. 6d.; basic, 52s.; Derbyshire, No. 3 foundry, 50s. to 52s.; ditto, No. 4 forge, 48s. 6d. to 49s., all per ton net, delivered Sheffield or Rotherham.

The Steel Trades.

The year is ending with many evidences of activity in the steel trades, armament material and other specialities being chiefly noteworthy. Manufacturers are busy fulfilling specifications for shipbuilders and marine engineers, and a good deal of work of this character, which was postponed during the recent lock-out, is now being put in hand again. Very few complaints are heard among manufacturers having a good connection with the shipyards. It is also hoped that the New Year will bring a revival in the demand for engineers' tools, files, &c. Makers of special steels for the motor trade are reported to have booked enlarged orders. The agricultural machinery industry has also placed good orders for steel, parts, &c. The foreign and colonial demand for high-speed steel, twist drills, special steels, cutlery and plate, sheets and wire, is being well maintained at the high level recorded during the past twelve months. Bar iron makers are busier on specifications, but prices remain unsatisfactory.

NORTH OF ENGLAND.

(From our own Correspondent.)

Cleveland Pig Iron.

PRODUCERS of Cleveland pig iron are having a better experience this week than has been reported for some weeks. They have booked fair orders, and have realised higher prices than have ruled at any other time during the current quarter, or, indeed, since the spring, and this has stimulated consumers to buy. No. 3 Cleveland G.M.B. pig iron has been realising as much as 50s. 1½d. per ton for prompt f.o.b. delivery. There has not been much done on the warrant market; indeed, it is a long time since there was so little speculation. Only very small lots change hands. The fact is that though there is half a million tons of Cleveland pig iron in stock it is held in very few hands, and they are wealthy people, who can afford to wait, though it is very expensive carrying these warrants, taking into account rent, interest, &c. But the holders are apparently so convinced of good advances next year that they are content to keep the warrants in their own hands. It is, however, surprising to see the warrant market fluctuate so little, considering how quickly the stock in Connal's store is increasing. On Wednesday 519,265 tons of Cleveland pig iron were held by Connal's, 12,198 tons increase for the month, and nearly 130,000 tons for the year, yet the fluctuations in the prices of warrants move within very narrow limits. There is no doubt that if the stock of warrants were distributed among a number of small holders who are influenced by comparatively insignificant circumstances prices would be nothing like so steady as they have been. The reports from Germany and the United States this week have not been favourable, and the price of warrants on Wednesday receded to 49s. 10d. cash buyers. It was stated that 10,000 tons of Alabama pig iron had been sold to Italy, and that there were negotiations in progress for further sales. That was rather depressing, because Italy is one of Cleveland's chief markets. The price of No. 3 Cleveland G.M.B. pig iron generally this week has been 50s. per ton for prompt f.o.b. delivery, with No. 1 at 53s. 6d., No. 4 foundry at 48s. 9d., No. 4 forge at 48s. 6d., and mottled and white at 48s., while 9d. to 1s. more has to be paid for delivery over the first quarter of next year.

Hematite Pig Iron.

Improvement in demand is generally reported by the producers of East Coast hematite pig iron, and prices have been put up 6d. per ton this week. Since the lock-out in the shipbuilding industry has terminated the position of hematite iron makers has become altogether satisfactory, and everyone expects to see this week's rise followed by further advances, and consumers are showing anxiety to buy well ahead—further ahead, in fact, than makers care to go in face of a rising market, not only for pig iron itself, but also for materials. Buyers will not offer enough for long forward delivery to tempt the ironmasters to commit themselves, for the latter want rather heavy premiums on prompt prices for delivery ahead. Certainly producers stand greatly in need of higher prices, for there can be little doubt about the unprofitableness of recent prices, the cost of materials being quite out of proportion to the rates ruling for the pig iron. Makers will lose nothing by waiting, seeing how active the shipbuilding industry and the plate and angle trades promise to be over the coming year, and, in fact, all round trade is reviving. Easier prices can hardly be looked for, particularly as there is no stock of hematite pig iron in the public stores and little in makers' hands, so that the operations of speculators do not trouble makers as they do in the ordinary Cleveland iron trade. Mixed numbers of East Coast hematite pig iron have this week been raised to 64s. per ton for prompt delivery, 64s. 6d. has to be paid for delivery over next month, 65s. for delivery over the first quarter of 1911, and 65s. 6d. for delivery over the second quarter. The last-named figure would be given for delivery over the whole of the year, but that is not enough to tempt producers.

Ore and Coke.

Merchants have put up the quotations for Rubio ore, and they are asking 21s. 6d. to 22s. per ton for delivery Tees or Tyne over next half-year. Thus hematite iron makers are not doing so well as at the commencement of this year, for then they could get 67s. per ton for mixed numbers East Coast hematite pig iron, and could get their ore at 19s. 6d. per ton; now 64s. is the price of the pig iron, and 21s. 9d., on the average, must be given for the ore. The ironmaster, in fact, has to pay out for ore alone about one-third of what he realises for his pig iron. Naturally the con-

sumers say they have to pay too much for their ore. Swedish Gellivare ore ranges from 22s. to 25s. per ton, according to quality, delivered on Teesside. Furnace coke, after being weak in price for a long time, has become decidedly stronger this week; in fact, by fully 6d. per ton. The stock that had accumulated at the collieries, and was the cause of considerable weakness in the market, for there was great pressure to sell, has been got rid of, and there is the extra demand which is usual just prior to the Christmas holidays. This has led to the average price being advanced to 16s. per ton, delivered equal to Middlesbrough works. Coke during the last few weeks has been cheaper than at any time during the last two years.

Manufactured Iron and Steel.

The position in nearly all branches of the finished iron and steel industries has become distinctly more favourable to the manufacturers, and the outlook is regarded as altogether encouraging. What has had an excellent influence on the market has been the termination of the lock-out in the shipbuilding industry, and, further than that, the settlement of the wages in the shipbuilding and engineering industries for the next five and a-half years. Such arrangements are not needed in the iron and steel trades, because in nearly every branch the regulation of wages is determined by sliding scales based upon the prices realised for what is manufactured. In the finished iron trade such a sliding scale has been in force since the spring of 1872. The opinion is general that 1911 will be a busy year, and traders are therefore in the best of spirits. But it cannot be reported that any advances of quotations have been made of late, though higher prices are generally expected. Steel ship plates to-day are quoted at £6 15s., iron ship plates at £6 12s. 6d., steel ship angles at £6 7s. 6d., iron ship angles at £7, packing iron and steel at £5 15s., iron ship rivets at £7 7s. 6d., steel bars at £6 5s., iron bars at £7, steel hoops at £6 12s. 6d., steel strip at £6 10s., steel joists at £6 5s., steel sheets at £7 7s. 6d., all less 2½ per cent. f.o.t. Galvanised and corrugated steel sheets are at £11 5s. per ton, less 4 per cent. f.o.b. for 24 gauge. Heavy steel rails are firm, at £5 10s., and cast iron railway chairs at £3 10s., both net f.o.b.

Shipbuilding.

Work at the shipyards is fairly under way this week. It was possible to start only a comparatively few of the men on the day after the termination of the lock-out last week, but a fair start at most yards was made, and now nearly the normal number of hands are engaged. Fortunately the weather has improved, so that outside work can go on uninterruptedly. At the ship repairing yards operations have not been started so quickly, because through the lock-out the employers have lost many orders, steamers having been sent elsewhere where firms could guarantee that the work would be completed without delay. With the holidays so near at hand, few orders for new vessels have been booked this month; but that is of no consequence when so many orders are already booked. They could not undertake now to give delivery of new vessels except at some considerable time ahead, as most of them have work booked which will keep their yards going nearly all next year. In these circumstances builders are quoting higher prices for new tonnage than they have asked for the last two or three years. Things should be better in the New Year, and the position of the employers is certainly more satisfactory than for a long time, seeing that a permanent working agreement has been arranged with the men, who have been conceded an immediate advance of 1s. per week on time wages, another 1s. six months hence, and then wages will remain unchanged for five years at rates which will be the highest ever known in the trade.

Cleveland Miners' Wages.

Sir David Harrell, the umpire in the recent arbitration respecting the wages of sections of the underground detail men employed at the Cleveland ironstone mines, has this week given his award, and has given advances to a large number of men—backbye deputies or shiftmen (*i.e.*, all men timbering away from the face), platelayers, labourers. Those who have a base rate of 3s. 6d. to 4s. 4d. per shift will get 3d. per shift advance, the advances to take effect from November 21st.

Coal and Coke.

Better accounts of business are given by those engaged in the coal trade, the demand and prices are more satisfactory, and anticipating that higher figures will have to be given next year, for fuel consumers are buying more freely than for months. Contracts for large quantities of steam and gas coals have been placed in this district during the current month, and there buyers who are anxious to arrange for supplies for delivery over the whole of 1911. Best steam coals have been advanced to 9s. 9d. per ton f.o.b., and 10s. has also been paid; best gas coals are up to 9s. 4½d., and seconds to 8s. 9d., while bunkers are up to 9s. for ordinary qualities and 9s. 6d. for best. Coke is dearer, 17s. 6d. f.o.b. being paid for foundry coke, 16s. for furnace coke, and 14s. 6d. for gas coke. The North-Eastern Railway Company has given the contract for the erection of new coal staiths and railway sidings at West Dunston to Messrs. Mitchell Brothers (Limited), Glasgow and London. The work will cost over £100,000, and is to be completed in two years. At Blythe new coal shifting facilities on the north side of the harbour are about to be started, this involving an expenditure of about £230,000 to be spread over the next three years, and extensive docks are also to be provided on the east side of the harbour for the import trade. On Tuesday Sir David Harrell acted as umpire on the wages' question at a meeting of the Durham Coal Trade Conciliation Board. The men asked for a 2½ per cent. advance, but the employers contended that the state of trade had been such as to call for a reduction rather than an advance. The case for the men was stated by Mr. John Wilson, and Sir Hugh Bell, Bart., replied for the owners. The umpire will give his award shortly.

NOTES FROM SCOTLAND.

(From our own Correspondent.)

The Pig Iron Warrant Market.

THE warrant market has been quiet since last report, so far as Cleveland iron is concerned. With certain fluctuations, the prices on the whole have held, and even been improved upon. Business has been done in Cleveland warrants at 49s. 10d. to 50s. 2d. cash, 50s. 1d. to 50s. 4½d. for delivery in one month, and 50s. 8d. to 50s. 10d. three months. A lot of warrants also changed hands at 50s. 1d. for delivery in twelve days. While the business is not very large at present, being restricted amongst other considerations by the near approach of the holidays, the market has shown a good deal of sensitiveness on some days. For example, the putting of 2400 tons of iron into store at Middlesbrough on Monday attracted more than usual attention, and the report that some large sales of Alabama iron had recently been made for shipment to Italy, was also a point brought into play in the iron ring. But the tone was well maintained, and dealers seem generally disposed to maintain a hopeful view of the situation.

Revival in Hematite Iron.

There has been a steady increase in the business in Cumberland hematite warrants in this market during the past month, and the amount of iron now changing hands is considerable. Four weeks ago Cumberland warrants were sold at 64s. cash, and there has since been an advance in price of 1s. 9d. per ton. Business has been done in this class of iron this week at 65s. to 65s. 9d. cash, 65s. 6d. for delivery in one month, 67s. 6d. two months, and 66s. 6d. to 66s. 10½d. three months, all for delivery in the Cumberland district. Merchants report that Scotch hematite pig iron has recently been sold for delivery over the first three months of the new year at 69s., less the usual 5 per cent., delivery in West of Scotland at steel works; but in the last day or two makers are represented as holding for 70s. per ton.

The Foreign Ore Trade.

During the prolonged strike at Bilbao, users of ore had little or no difficulty in obtaining full supplies. The output of hematite pig iron at no time sustained material interruption. Some of the users of ore, indeed, have large stocks to work upon. The imports for the year to date are 150,000 to 160,000 tons larger than at this time last year. It is reported that importers in several instances have large arrears of delivery of Bilbao ore to make up. There appears, on the whole, to be an assurance of ample supplies. At the same time the matter of price occasions some anxiety. Sellers are quoting 22s. a ton for good ore, and this price is so high that users feel they cannot afford to pay it unless there should be a considerable further appreciation in the value of hematite iron.

Scotch Pig Iron Trade.

The prices of Scotch pig iron are generally firmer, and in some cases 6d. higher in sympathy with the general condition of the market. Business in common and special brands has been on a fair scale for the season, and the shipments have been showing rather better. Govan and Monkland, f.a.s. at Glasgow, are quoted, Nos. 1, 57s. 6d.; Nos. 3, 56s. 6d.; Carnbroe, No. 1, 60s. 6d.; No. 3, 57s. 6d.; Clyde and Calder, Nos. 1, 62s. 6d.; Nos. 3, 57s. 6d.; Gartsherrie, No. 1, 63s.; No. 3, 58s.; Summerlee, No. 1, 64s. 6d.; No. 3, 59s. 6d.; Langloan, No. 1, 65s.; No. 3, 60s.; Coltness, No. 1, 82s. 6d.; No. 3, 61s.; Shotts, at Glasgow or Leith, No. 1, 63s. 6d.; No. 3, 58s. 6d.; Eglinton, at Ardrossan or Troon, No. 1, 58s.; No. 3, 57s.; Glengarnock, at Ardrossan, No. 1, 64s.; No. 3, 59s.; Dalmellington, at Ayr, No. 1, 60s. 6d.; No. 3, 58s.; Carron, at Grangemouth, No. 1, 63s. 6d.; No. 3, 58s. 6d. per ton. The output is maintained, there being 86 furnaces in blast in Scotland, compared with 84 at this time last year.

Shipments of Pig Iron.

The shipments have been better than usual, but the larger proportion, 5026 tons, went coastwise, the exports amounting to only 1353 tons. The total of 6379 tons, compared with 4574 in the corresponding week. Of the foreign shipments 275 tons went to Canada, India 110, Australia 125, France 75, Germany 80, Russia 10, China and Japan 89, other countries 484 tons. The arrivals at Grangemouth of pig iron from Cleveland and district were smaller than of late, amounting to 8632 tons, and showing a decrease of 2980 tons, compared with the quantity received in the corresponding week of last year.

Finished Iron and Steel.

The steel trade has now much better prospects, owing to the resumption of work in the shipyards, but it is too soon to anticipate the nature or extent of the business, owing to the intervening holidays. The actual state of employment at the works is still to some extent unsatisfactory. It is reported that shipbuilders are taking delivery of material that had accumulated during the lock-out, and until this is exhausted fresh business may not readily be secured by the steelmakers. In some cases, however, good recent contracts have been obtained, in connection with which specifications are expected to be available without delay. As regards a variety of general structural material, merchants seem to be in a position to quote somewhat below the last fixed prices of merchants under contracts of earlier date, and are thus in an advantageous position for securing current business. The manufactured iron trade is quiet, with moderate employment, as a rule. Makers of cast iron pipes have better prospects, and an order of some importance has been obtained for South America.

The Coal Trade.

The coal trade is fairly active for the season, but there has been less disposition in the last few days to enter into fresh business. It is thought probable that advances in price have discouraged some buyers. On the other hand, coalmasters are generally prepared to make some concession in cases of good actual business. Prices are nominally as last week. House coal has been selling very well, considering the open condition of the weather.

WALES AND ADJOINING COUNTIES.

(From our own Correspondent.)

Last Week's Coal Trade.

THE stormy weather, as usual, interfered a good deal with traffic and gave a reduced percentage of trade; still it was observable that there was more firmness in business, and prompt loading was more to the front. There was a conviction on 'Change that the disastrous strike was abating, and members were confident that though a general collapse of the strike was not likely, still the collieries would give way one by one, the weaker ones first, and very soon all would be working. This probably was too hopeful. The character of the colliery population is altering, the old-fashioned and more docile Welsh collier being replaced by a mixture of nationalities, more aggressive and tenacious of considered rights. As many thought, some sections of the men are yielding, and another promising feature is that the strike area has been confined. Dowlais and Cyfarthfa have remained firm, and the principal upset has been in the Rhondda and Aberdare.

Latest State of Trade: Present Quotations.

At Cardiff this week the market opened quietly, and the position of affairs was declared to be unchanged; stems were reported so full that it was impossible to arrange fresh business. Few, if any, of the leading coalowners had any coal to spare, and for spot parcels to complete cargoes higher prices were required. The latest news regarding the strike, eliminating the rumours, is that with regard to the Aberdare Valley the position remained. The men at Cwmamman, Bwllfa, Blaennant, and the smaller collieries, who came out in sympathy with the Powell Duffryn, are at work, and a considerable quantity of coal is being raised. The whole of the Powell-Duffryn men are still idle. There was a great military concourse at Pontypridd on the occasion of the trial for alleged violence and intimidation against several colliers at Gilfach Goch. The hearing was extended over six days, and on Tuesday the decision was given. Two of the defendants were sentenced to terms of imprisonment, others were fined, and the charge against seven dismissed. Latest prices:—Best steam coal, 16s. 6d. to 17s.; best seconds, 16s. to 16s. 6d.; ordinaries, 15s. 3d. to 15s. 9d.; best drys, 16s. to 16s. 6d.; ordinary drys, 15s. to 15s. 9d.; best washed nuts, 14s. to 14s. 6d.; seconds, 13s. 3d. to 13s. 9d.; best washed peas, 12s. to 13s.; seconds, 10s. 6d. to 11s. 6d.; best bunker smalls, 9s. 6d.; best ordinaries, 8s. 6d. to 9s.; cargo smalls, 7s. 9d. to 8s. 3d.; inferior sorts, 7s. to 7s. 6d.; best Monmouthshire black vein, 15s. to 15s. 6d.; ordinary Western Valley, 14s. 3d. to 14s. 6d.; best Eastern Valley, 13s. 3d. to 13s. 7d.; seconds, 12s. 6d. to 12s. 9d. Bituminous coal: Very best households, 17s. 6d. to 18s.; best ordinaries, 14s. 6d. to 16s. 6d.; No. 3 Rhondda, 17s. to 17s. 6d.; brush, 13s. 3d. to 13s. 9d.; smalls, 9s. 6d. to 10s.; No. 2 Rhondda, 12s. 3d. to 12s. 9d.; through, 10s. to 10s. 6d.; smalls, 7s. to 7s. 6d. Patent fuel, 14s. 9d. to 15s. 6d. Coke: Special foundry, 24s. to 26s. 6d.; foundry, 18s. to 20s., 16s. 3d. to 17s. 3d.

Newport, Mon., Coals.

A good deal of firmness prevails in the trade. Figures show that there has been a good run of business, over 90,000 tons coal having been shipped during the past week to foreign destinations and 12,183 coastwise. The storms have been severe. Smalls getting stronger. Latest:—Very best black vein, 14s. 9d. to 15s. 3d.; Western Valley, 14s. to 14s. 3d.; Eastern Valley, 13s. to 13s. 6d.; other kinds, 12s. 3d. to 12s 9d.; best smalls, 7s. 3d. to 7s. 9d.; seconds, 6s. 9d. to 7s. 3d.; inferiors. 6s. 3d. to 6s. 9d. Bituminous:—Best households, 15s. 6d. to 16s. 6d.; seconds, 14s. to 15s.; patent fuel, 14s. 6d. to 15s. Coke: Foundry, 18s. to 19s.; furnace, 16s. 6d. to 17s. 3d.

Swansea Coals.

The weather affected the port last week to the extent of about 40,000 tons. There was an improvement in patent fuel. The shipment of both coal and patent fuel was limited to 62,687 tons. This week there was improved business. Anthracite firm; good demand for Swansea large; values higher; red vein better. Some machine coals harder. Latest:—Best malting, 23s. to 24s. net; second, 17s. 6d. to 18s. net; big vein, 16s. 6d. to 17s., less 2½; red vein, 11s. 6d. to 12s. 6d., less 2½; machine-made cobbles, 21s. to 23s. net; Paris nuts, 23s. 6d. to 25s. net; French nuts, 23s. 6d. to 25s. 6d. net; German nuts, 23s. 6d. to 25s. 6d. net; beans, 19s. 6d. to 21s. net; machine-made large peas, 10s. to 11s. 6d. net; fine peas, 9s. to 10s. net; rubbly culm, 5s. 3d. to 5s. 9d., less 2½; duff, 2s. 3d. to 2s. 9d. net. Steam coal: Best large, 17s. to 18s.; seconds, 13s. 6d. to 15s.; bunkers, 10s. 3d. to 11s. 6d.: small, 6s. 9d. to 7s. 6d., all less 2½. Bituminous: No. 3 Rhondda, 18s. to 18s. 6d.; through, 15s. to 15s. 6d.; small. 10s. 6d. to 11s.; patent fuel, 13s. 3d. to 13s. 6d., all less 2½, cash, 30 days.

Port Talbot.

The industries, as well as the shipping, have passed through a trying week, and the aggregate tonnage was limited to 41,328 tons. In tin-plates 227 tons were dealt with. In coal 30,728 tons were exported foreign, and 4630 tons coastwise; in pig iron, 726 tons were imported.

Tin-plate.

The shipments of tin-plates last week were 102,204 boxes, receipts from works 79,064 boxes, and there now remain in vans and warehouse 170,005 boxes. These figures show that independently of the weather a good week's work was done. The trade continues sound and hopeful. Loadings are evidently influenced by the storms, which have continued to affect the Channel severely, and have undoubtedly lessened tonnage. We note this week a falling off in clearances for the Far East, but New York figures are satisfactory. The make at neighbouring parts has been well maintained. In the Swansea Valley the old members say that there is no relaxation, and that, as is generally the case at this time of year, every size and gauge is being worked off the order books of the large firms. Of late the sheet trade has brightened the last two or three months. Midweek the market was reported strong and active, and no falling off in the demand. Prices this week were firm, with an advancing tendency. For delivery over the first quarter of next year a premium is obtainable. Present prices:—Bessemer and Siemens primes, ordinary plates, I.C., 20 × 14 × 112 sheets, 14s. 1½d. to 14s. 3d.; odd sizes, basis, 14s. 9d.; C.A. roofing sheets, £9 5s. to £9 10s.

Iron and Steel.

Satisfaction was expressed at the substantial work done last week at Dowlais. There was a very large make of finished steel, tin bars, sleepers, and rails. The Goat Mill was very busy, and the Big Mill gave a large make of light rails, angles, curves, props, &c. The blast furnace management reported a brisk week. As a natural course the activity in mills and furnaces told well throughout. Large despatches are to be made; one of 4500 rails to Buenos Aires was made last week. One came in from Algiers and Salangen. 900 tons pig from Maryport, 2733 tons steel from Antwerp, and 2100 Rotterdam for Newport. At Llanelly and Swansea Valley the make of steel has been well maintained. Blast furnace at Llandore busy. Latest quotations:—Pig iron: Hematite, mixed numbers, 65s. 7½d. cash, 65s. 11½d. month; Middlesbrough, 49s. 11d. cash, 50s. 3d. month; Scotch, 56s. cash, 56s. month; Welsh hematite, 70s. 6d. to 71s. delivered; East Coast hematite, 69s. to 70s. delivered; West Coast hematite, 70s. to 70s. 6d. c.i.f. Steel bars: Siemens, £5 to £5 2s. 6d.; Bessemer, £5. Rubio ore, 20s. 3d. to 20s. 9d., basis of 55 per cent. iron. Other quotations:—Copper, £57 2s. 6d. cash, £57 17s. 6d. three months. Lead: English, £13 15s.; Spanish, £13 5s. Spelter, £23 17s. 6d. Silver, 25 5/8d. per oz.

GLASGOW TECHNICAL COLLEGE SCIENTIFIC SOCIETY.—At a meeting of this body, held in the college on December 10th—Mr. George Ness presiding—Mr. John S. Glen Primrose read a paper on "Metallography as an Aid to the Engineer." Describing first the methods of operation in the micro-photography of metals and the various methods of illumination of the objects, the author showed later the effects of various substances added to irons, and showed the change of structure of steel with different amounts of carbon. The effect of the treatment of the materials was referred to, and a series of interesting lantern slides and actual micrographs were exhibited on the screen to show such faults as slag inclusions, &c. which accounted for the failure of various structures.

THE INSTITUTION OF CIVIL ENGINEERS: STUDENTS' MEETINGS.—At the students' meeting held at the Institution on Friday, the 16th December, at 8 p.m., Mr. C. S. Meik, M. Inst. C.E., in the chair, Mr. R. N. Mirza read a paper on "Calculation of the Most Economical Ratio of Steel in Reinforced Concrete Beams and Slabs." The author, basing his calculations upon the usual stresses of 600 lb. and 17,000 lb. per square inch in the concrete and steel respectively, evolved a formula from which could be estimated the total cost of a structure, having given the ratio of cost of concrete and steel per unit. The paper was supplemented by curves drawn to show the varying cost of the structure with different percentages of reinforcement, and the most economical ratio for practical use. The paper was followed by a good discussion, the chairman, in his remarks, drawing attention to the greater reliability of steel compared with concrete, and the proportionately higher factor of safety required in the latter material. The following students spoke:—Messrs E. F. Hunt, G. F. Walton, G. A. Clark, H. J. Gourley, and A. J. Hart.

THE SOCIETY OF ENGINEERS.—The first annual general meeting of the Society of Engineers (Incorporated) was held, on the 12th inst., at 17, Victoria-street, Westminster, Mr. Diogo A. Symons, M. Inst. C.E., president, in the chair. The Council and officers for 1911 are as follows:—President, F. G. Bloyd; vice-presidents, J. Kennedy, A. Valon, H. C. H. Shenton; members of Council, Professor Henry Adams, C. T. Walrond, Norman Scorgie, Percy Griffith, T. E. Bower, Henry C. Adams, J. R. Bell, S. Cowper-Coles, Frank Latham, H. P. Maybury; associate member of Council, E. Scott Snell; hon. secretary and hon. treasurer, D. B. Butler. The following premiums in respect of papers published in the *Journal* during 1910 have been awarded:—The President's gold medal to Mr. W. C. Easdale, "Sewage Disposal Ideals;" the William Clarke prize, value £5 5s., to Mr. S. M. Dodington, "Public Slaughter-houses;" the Bessemer premium, value £5 5s., to Mr. C. W. V. Biggs, "The Inspection and Testing of Engineering Materials and Machinery;" the Nursey premium, value £3 3s., to Mr. Henry C. Adams, "Current Professional Topics;" a Society's premium, value £3 3s., to Mr. A. H. Allen, "Electricity from the Wind;" a Society's premium, value £3 3s., to Mr. C. R. Enock, "Engineers and Empire Development." The chairman presented the report of the Council, which showed that the formation of the Society, by the amalgamation of the Society of Engineers and the Civil and Mechanical Engineers' Society, had been fully justified by the success of the first year's work.

NOTES FROM GERMANY, FRANCE, BELGIUM, &c.

(From our own Correspondent.)

Rheinland-Westphalia.

THERE has been less firmness in iron and steel during this and the previous week; bars have been offered at M. 105 p.t., while the Convention price is M. 112 to M. 114 p.t. Few forward orders are booked, consumers showing a marked desire to await the further development of the iron industry before they place any large contracts.

The Silesian Iron Market.

A regular activity is reported from the different trades. Scrap iron met with an advance in price in November; the increasing consumption was expected to cause purchasers to be willing to pay what was asked, but they have shown a decided disinclination to purchase the increased rates.

The Steel Convention.

Deliveries of the Steel Convention in November of the present year were 420,306 t., as compared with 459,449 t. in October of the present year, and as compared with 390,355 t. in November, 1909. Deliveries accordingly were 39,143 t. lower than in October and 29,951 t. higher than in November last year. Of the sales in November, 142,049 t. were semi-finished steel, as compared with 131,712 t. in October, and as compared with 130,480 t. in November last year; railway material, 162,450 t., as compared with 181,978 t. in October, and with 153,265 t. in November last year; sectional iron, 115,807 t., as compared with 145,759 t. in October, and with 106,610 t. in November, 1909.

List Quotations.

The following are the present list rates per ton free at works:—Raw spathose iron ore, M. 10.90; roasted ditto, M. 15.50; Nassau red iron ore, M. 12.50 to 13; spiegeleisen, 10 to 12 per cent. grade, M. 63 to 65; white forge pig, Siegerland brands, M. 58 to 60; Rhenish-Westphalian quality, M. 59 to 60; iron for steel making, M. 59 to 62; German Bessemer, M. 70; basic, free Luxemburg, M. 53 to 55; Luxemburg forge pig, free Luxemburg, M. 48 to 50; Luxemburg foundry pig, No. 3, M. 52 to 53; German foundry pig, No. 1, M. 66; No. 3, M. 64; German hematite, M. 70; bars in basic, M. 112 to 115; iron bars, M. 130 to 133; hoops in basic, M. 140 to 145; steel plates, common quality, M. 122 to 124; boiler plates, M. 132 to 134; sheets, M. 140 to 145; drawn wire in iron or steel, M. 130.

The German Coal Market.

Increasing life was reported from Upper Silesia; the total deliveries during the last two weeks of November were 10,881 wagons per day, as compared with 9718 wagons during the same period last year, and as compared with 10,657 wagons during the last two weeks of October. All descriptions of fuel are in strong request. From the Rhenish-Westphalian coal district also an increase in demand and inquiry for engine and house fuel is reported. Stocks are fairly large, the want of wagons having caused a falling off in deliveries of 175,000 t. in November. In South Germany stocks are about the same as before; business there is considerably hampered by the keen competition from the Saar and Ruhr coal district. Up to end of the present year the Coal Syndicate intends to maintain a reduction in output of 15 per cent. for coal, 25 per cent. for briquettes, and 27 per cent. for coke. The export trade of the Rhenish-Westphalian Coal Syndicate developes pretty satisfactorily; shipments on the Rhine to Holland were, for the first ten months of present year, 2,884,827 t., as compared with 2,401,834 t. in the corresponding period the year before. Deliveries to Belgium have also increased, especially those by water; they were 1,815,252 t. for the first ten months of present year, as compared with 1,429,357 t., while to France only 92,913 t. were sent, as compared with 95,554 t. in 1909. Transmarine business in coal is pretty active.

Austria-Hungary.

The condition of the iron market is fairly good; large sales are rather an exception, but a stiff tone is generally felt. The abnormally mild weather was most favourable to the building department, and present employment, as well as prospects, are good in this branch. The trade in fuel is healthy.

The Belgian Iron Market.

A firm position is reported from the different branches. Sales in forge pig are effected at 66·50f. p.t., and 72f. to 74f. p.t. is quoted for foundry pig, No. 3 and for basic. The Comtoir des Aciéries Belges has resolved to maintain the present prices of 98f. p.t. for bars, 106f. for billets, and 113·50f. for plates; also in the next quarter, with the usual ristorno of 7·50f. p.t. for orders of at least 1000 tons per month, while for smaller purchases only 5f. p.t. will be granted. Slowly but steadily prices tend upwards in the finished iron department. Rails continue lively, whereas the demand for girders has slackened off lately. Regular activity and a stiffening tendency was reported from the Belgian coal market, and a good trade is likely to be done in the next quarter also.

METAL-CUTTING WITH OXYGEN.—Questions are frequently asked as to the cost of metal cutting with oxygen. Published figures being taken from straight cuts under favourable conditions are no guide for practical work under ordinary conditions. It will therefore be of great interest to know that on Monday, the 19th, one man employed by the Knowles Oxygen Company, of Wolverhampton, cut through 42 girders, 15in. by 5in. section, in four and three-quarter hours in the open at the railway sidings at Small Heath, Birmingham. The gases used amounted to less than 300 cubic feet of hydrogen and 200 of oxygen. With oxygen at £2 per thousand cubic feet, hydrogen at £1 per thousand cubic feet, and labour at 1s. per hour, the cost worked out at 18s. 6d., or under sixpence per cut.

HOUSE REFUSE MADE INTO ROAD PAVING.—A bronze medal has been awarded to Goddard, Massey and Warner, Limited, sanitary engineers, Nottingham, by the road experts appointed by the Royal Sanitary Institute. This award was made after inspection of the roads laid by the borough of Kensington, the roads inspected in some cases having been laid over four years. The paving blocks are made from refuse clinker residue, which is ground in a mill of special design; the material at the same time is screened through the bottom of the mill. It is then raised by special machinery and discharged into a heater, and afterwards passes into a second elevator, which raises it into a measuring hopper; and from there into a special mixer, where preparations of Trinidad lake asphalt and oil are added and thoroughly mixed. Then it is discharged into another hopper leading to the paving block press for moulding the mixture into paving blocks the same size as wood blocks. At the Kensington destructor works over 500 paving blocks, which weigh about 10 lb., and are in size 9in. by 4½in. by 3in., are made per hour. They are turned out of the block press in regulated numbers to a conveyor and through a water-cooling process, and are then ready for laying without any delay or storage. The blocks are said to wear exceedingly well, and among the qualities claimed for them are that they are sanitary and take little scavenging, that they are non-slippery, not in any way affected by the weather—frost or sun—and are perfectly noiseless when traffic is passing over them. The whole of the machinery employed is the invention of Mr. William Warner, managing director of Goddard, Massey and Warner, Limited, Traffic-street Nottingham, who are the sole manufacturers.

BRITISH PATENT SPECIFICATIONS.

When an invention is communicated from abroad the name and address of the Communicator is printed in italics.

When the abridgment is not illustrated the Specification is without drawings.

Copies of Specifications may be obtained at the Patent-office Sale Branch, 25, Southampton-buildings, Chancery-lane, London, W.C., at 8d. each.

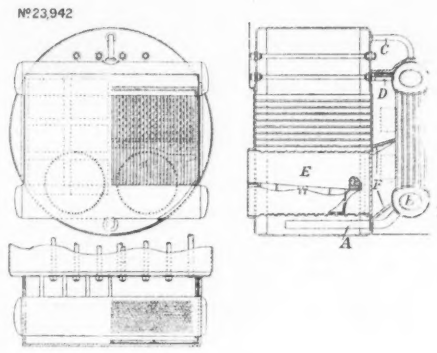
The first date given is the date of application; the second date at the end of the abridgment is the date of the advertisement of the acceptance of the complete specification.

Any person may on any of the grounds mentioned in the Acts, within two months of the date given at the end of the abridgment, give notice at the Patent-office of opposition to the grant of the Patent.

STEAM GENERATORS.

23,942. October 19th, 1909.—IMPROVEMENTS IN STEAM GENERATORS, John McLaren and John Weir, both of 62, Leadenhall-street, London, E.C.

This generator may be described as a combined Scotch and water-tube boiler. The water circulates from the Scotch boiler by way of the tube A into the lower drum B of the water-tube boiler. Steam and water return from the water-tube boiler to the Scotch

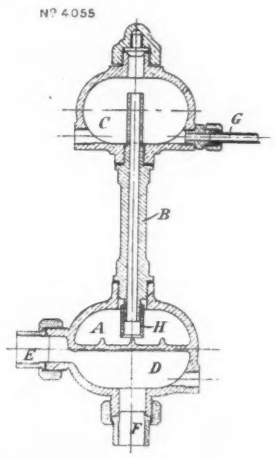


boiler by way of the tubes C, D. The hot gases leaving the furnace E are deflected by baffles F so as to pass through the lower half of the tubes in the water-tube boiler. Thereafter the gases return through the upper half of the water-tube boiler tubes, and so pass by way of the fire tubes in the Scotch boiler to the uptake. The drums and tubes of the water-tube boiler extend across the full width of the fire-tube boiler.—*November 30th*, 1910.

CONDENSERS AND FEED-WATER HEATERS.

4055. February 18th, 1910.—IMPROVEMENTS IN FEED-WATER REGULATORS FOR STEAM BOILER, George Augustus Mower and Henry Wilmot Spencer, both of 147, Queen Victoria-street, London.

The chamber A contains a vaporisable liquid, and is connected by a long pipe B to an expansion chamber C. Beneath the chamber A is another, D, provided with a connection E to the steam space in the boiler, and with a connection F to the water space. The heat of the steam or water within the chamber D

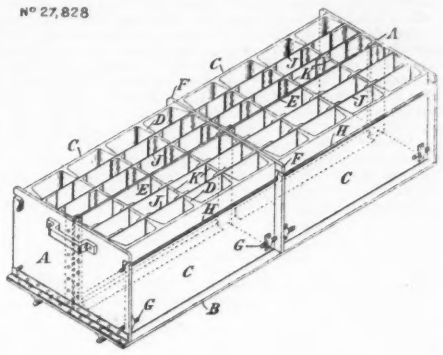


causes the liquid in the chamber A to vaporise, and the pressure of this vapour ascending into the expansion chamber C is transmitted by a connection G to a diaphragm or other device governing the supply of feed water. The long connecting piece B affords considerable cooling surface, thereby assisting rapid condensation and reduction of pressure within the reservoir C when the temperature within the chamber D falls, *i.e.*, when water is present therein. A threaded extension piece H, provided with a lock nut on the end of the pipe B, allows the depth of vaporisable liquid in the chamber A to be regulated as desired.—*November 30th*, 1910.

GAS PRODUCERS.

27,828. November 29th, 1909.—IMPROVEMENTS IN THE CARBONISATION OF COAL AND OTHER CARBONACEOUS MATERIAL, Robert William Pringle, 25, Ellerker-gardens, Richmond, Surrey, and Laurence Sloane Richards, 96, Hamlet-gardens-mansions, Ravenscourt Park, London.

In order to reduce the time required for the carbonisation process the fuel is introduced into the retort contained in a cellular box, as illustrated. This has the effect of dividing up the mass of fuel into a number of small parcels, and as the walls are of conducting material each parcel can be completely carbonised at low temperatures without the production of a layer of non-conducting coke surrounding it. In ordinary practice it is found that by the time the centre of the charge is completely carbonised the outside layers have become over carbonised. This invention overcomes this difficulty and produces a uniform quality of smokeless fuel. The box is composed of two end plates A A riveted to a base plate B, and has side plates C C provided with dividing ribs D D. There is a fixed longitudinal division wall E and a fixed cross wall F. The side plates C C are hinged as at G to the end plates and the cross wall, while a bar H holds each side plate in

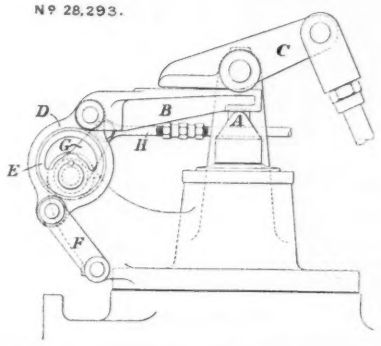


place as shown. J J are loose conducting plates fitted with partition pieces K K.—*November 30th*, 1910.

INTERNAL COMBUSTION ENGINES.

28,293. December 3rd, 1909.—IMPROVEMENTS IN GOVERNING MECHANISM FOR INTERNAL COMBUSTION ENGINES, Tangyes Limited, Cornwall Works, Soho, Staffs, and James Robson, 24, Sandwell-road, Handsworth, Staffs.

A is the stem of the admission valve or alternatively of a liquid fuel pump, and B is a slider resting upon it. The lever C driven from the cam shaft and working in conjunction with the slider B operates the admission valve at the required intervals in the usual manner. The left-hand end of the slider is connected by a

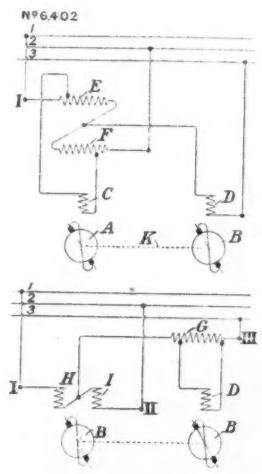


pin to the strap D of an excentric E. A link F couples the excentric strap to the main framing, as shown. The shaft carrying the excentric pulley is supported in brackets attached to the frame and carries a lever G which is coupled to the governor mechanism by a rod H. The engraving shows the mechanism as working under full load. If the load is reduced the governor pulls the excentric round, the end of the slider is lowered, and the lift of the valve will be less. A modification is described wherein a right and left-hand threaded screw with suitable nuts takes the place of the excentric.—*November 30th*, 1910.

DYNAMOS AND MOTORS.

6402. March 14th, 1910.—IMPROVEMENTS IN AND RELATING TO THE CONNECTION OF SINGLE-PHASE MOTORS TO POLYPHASE CIRCUITS, *Aktiengesellschaft, Brown, Boveri and Cie., Baden, Switzerland.*

Two single-phase motors, which are of the same size, and which are coupled together to a three-phase current network, without the aid of a transformer, are coupled in such a manner that the phases of the three-phase current network are equally loaded. The arrangement is such that the single-phase motors are driven from three-phase mains by taking current from part of the phases



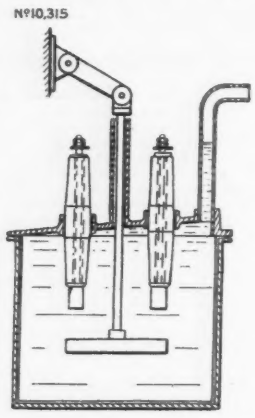
to drive one motor and current from the other part of the phases to drive the other, the two motors being suitably connected mechanically. The voltage for which the stator windings of the two halves of the motor must be designed are in the ratio of 1 : 0.87, and the case may arise, especially if the voltage of the network is low and the efficiency of the motor high, that the given voltages lead to inconvenient numbers of bars or slots for one or the other stator, if the condition of equality is to be maintained for both halves of the motor. This may be remedied by altering the voltage by a slight amount. The object of the present invention is to obtain a method of driving by altering the voltage as referred to above. The upper engraving shows an arrangement in which the suitable alteration of voltage is effected in driving

the motor A, and the lower engraving an arrangement where it is effected in driving the motor B. In the first case, two single-phase motors A and B are mechanically coupled, for example, as indicated at K. The motor A is driven or excited by the windings C, which is fed from two phases of a three-phase network through auto-transformers E and F, connected to the network at the terminals I. and II. The second motor B is connected to the third phase of the network at the terminals 3. Referring now to the lower engraving, the motors remain as before, but in this case the motor A is excited by windings H and I, connected to the network without transformers at the terminals I. and II., and the motor B is excited by the windings D, through an auto-transformer G, connected with the network at the terminals 3. It will be understood that the ratio of transformation in each case where transformers are used is adjusted to the proper amount for proper proportioning of the exciting windings consistent with convenient arrangement of them.—*November 30th*, 1910.

SWITCH GEAR.

10,315. April 27th, 1910.—IMPROVEMENTS IN OR RELATING TO ELECTRIC SWITCHES, Siemens Brothers, Caxton House, Westminster, S.W.

According to this invention an oil chamber in which the main body of oil is stationary and the circuit-breaking movement takes place entirely within the chamber is so arranged that the oil space

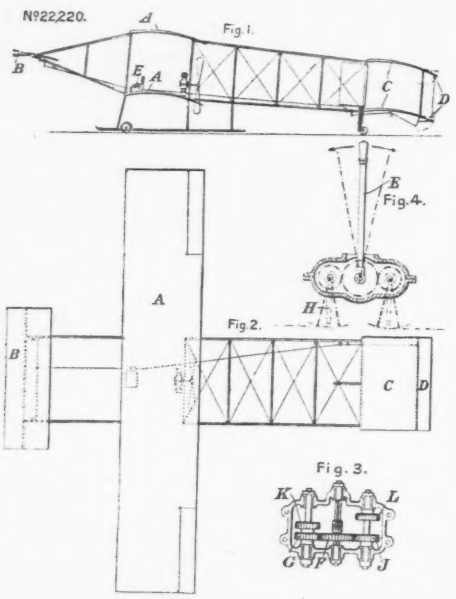


is completely filled, and that in addition to this the oil level extends upward either into a vent tube or into a narrow space enclosed by the rim of the oil vessel, so that the body of the oil is kept under a definite head or pressure as it were, whilst, however, any gas can rise through the upwardly extending portion of the oil, and so make its escape. A modification is also dealt with.—*November 30th*, 1910.

AERONAUTICS.

22,220. September 24th, 1910.—IMPROVEMENTS IN AEROPLANES, *Henry Farman, 22, Avenue de la Grande Armée, Paris.*

The machine illustrated is a Farman biplane comprising, as usual, two superposed supporting surfaces A A, a front elevating rudder B, and a tail composed of two superposed surfaces C C. The invention, however, applies to all types of aeroplanes, and is intended to re-establish the longitudinal equilibriums—hitherto the duty of the plane B—should this be disturbed. The invention consists of hinging to each of the tail surfaces C C an aileron D, these ailerons being controlled either simultaneously

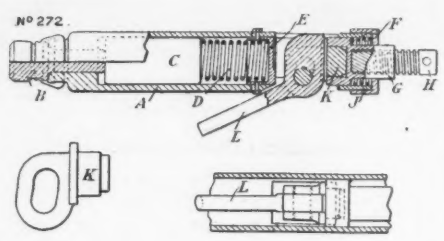


with or independently of the front elevating plane B. Figs. 3 and 4 show a mechanism for effecting such a control. The handle E is mounted on a central shaft carrying a gear wheel F. This wheel meshes with another G on a second shaft, which, by means of a lever H keyed to it and suitable connecting wires, controls the front plane B. The wheel F also meshes with another wheel J carried on a third shaft, which similarly controls the ailerons D. By sliding the wheel F and its handle along the central shaft the wheel F can be brought into mesh separately either with a wheel K on the second shaft or a wheel L on the third. The arrangement is such that when the front plane and the rear ailerons are being operated simultaneously they rotate in opposite directions. —*November 30th*, 1910.

MACHINE TOOLS AND SHOP APPLIANCES.

272. January 5th, 1910.—AN IMPROVED HOLDER-UP FOR PNEUMATIC RIVETERS, Charles Schofield, Milburn House, Newcastle-upon-Tyne.

This holder-up does not require compressed air, the reacting force being given by springs. The casing A carries at one end a freely sliding snap B, against which a piston C bears inside the casing. The piston C is acted upon by a spring D, which is held at its other end against a cap E. This cap is capable of sliding a short distance within the casing, its motion being controlled by two pins passing through slots in the walls. The right-hand end of the casing A is closed by a cap F, through which there passes a socket G, provided with a screw H. Between the socket and the

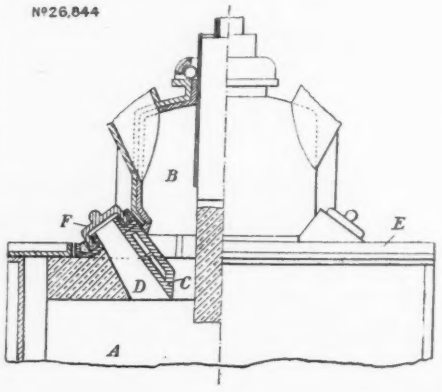


cap a spring J is disposed. The inner end of the socket is arranged to carry a two-armed fork K, each arm of which is slotted as shown. This fork carries a cam lever L, the casing A being suitably slotted to accommodate this lever. In use the screw H is adjusted to suit the given conditions, and on depressing the handle L the snap B is brought to bear against the rivet head partly by the motion of the cap E and piston C within the casing and partly by the motion of the instrument as a whole from the socket G.—*November 30th*, 1910.

MISCELLANEOUS.

26,844. November 18th, 1909. IMPROVEMENTS IN ELECTRIC FURNACES, *Dr. Alois Helyenstein, of 4, Pokornygasse XIX., Vienna, Austria.*

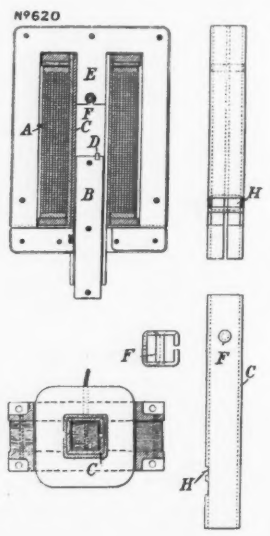
In electric furnaces with a superposed charging shaft through which the electrode runs it is found of considerable advantage to be able to overlook the admission of the material into the furnace, and the working of the furnace, and to regulate this from different places. This is ensured by the present invention through the provision in the top of the furnace laterally to the charging shaft of wide slots which can be closed so as to be gas-tight. On the actual furnace or reduction chamber A a charging shaft B is placed,



which receives the vertical electrode and opens into the furnace through the medium of a contraction cone C that is cooled with water. Shut off from this cone, but independent of the charging shaft several wide slots D are formed in the top E of the furnace, which run towards the middle of the furnace, and by means of the cover F and a sand-seal can be made gas-tight. These slots through which the place where the material passes out of the charging shaft into the furnace is made easily accessible fulfil requirements without which the working of closed furnaces cannot be easily carried on. In this way the furnace process can be overlooked as in open furnaces.—*November 30th*, 1910.

620. January 10th, 1910.—IMPROVEMENTS RELATING TO ALTERNATING CURRENT ELECTRO-MAGNETS, Wilfrid John Previte Orton, of the Westinghouse Works, Trafford Park, Manchester.

The operation of the apparatus is as follows:—Assuming that the magnetising coil A of the electro-magnet is de-energised, the armature B occupies the position in the tube C shown, and, when



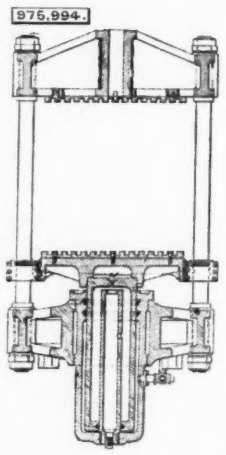
magnetising current is supplied to the coil, is drawn upwards in the tube C until the projection D engages with the face of the portion E of the central limb of the core. Owing to the presence of the short-circuited conductor, constituted by the rivet F and the tube C, the core B is maintained in its attracted position without vibration or chattering owing to the well-known action of the short-circuited conductor in maintaining the attraction between the portions E and B of the central limb of the core during the instant at which the magnetising current is passing through its zero value. The absence of vibration and chattering of the armature B when in its attracted position is further ensured by the provision of the second short-circuited conductor constituted by the portion of the tube C surrounding the opening H, which serves to exert a lateral pull on the lower part of the armature B, drawing the same into intimate contact with the left-hand side of the tube C, as will be readily understood. The projection D on the upper face of the armature prevents residual magnetism, and serves to assist this tendency by causing the lower portion of the armature to be tilted over towards the left-hand side of the tube so as to increase the frictional engagement between the said armature and the inner face of the non-magnetic tube. It will be understood that the additional short-circuited conductor provided by the portion of the tube surrounding the opening H may, if desired, be situated on the armature itself, and by suitably shaping either or both of the opposing faces of the portions E, B of the central limb, the projection D may be dispensed with.—*November 30th*, 1910.

SELECTED AMERICAN PATENTS.

(From the United States Patent-office Official Gazette.)

975,994. HYDRAULIC PRESS, *F. Phelps, Little Rock, Ark.—Filed June 7th*, 1909.

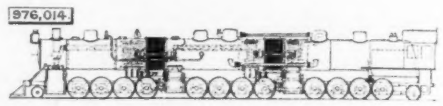
The plunger is hollow; inside it is placed a tube as shown. The pressure is at first that due to the difference in the area of the



inside of the plunger and the internal tube. As soon as the ram in its ascent passes the orifice in the internal tube, the water is admitted under the whole area of the ram, and so the final squeeze is obtained automatically. There are eleven claims.

976,014. ARTICULATED LOCOMOTIVE, *S. M. Vauclain, Philadelphia, Pa., assignor to Baldwin Locomotive Works, Philadelphia, Pa., a Corporation of Pennsylvania.—Filed October 9th*, 1909.

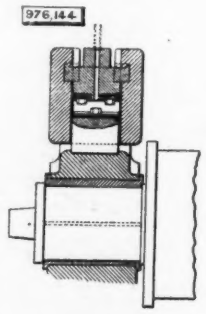
This patent is for the combination in a locomotive, of three frames, the frames being pivotally connected one to another, a boiler section on each frame, said boiler sections being flexibly connected, a high-pressure cylinder on the rear frame, an intermediate cylinder on the intermediate frame, a low-pressure cylinder on the forward



frame, driving mechanism connected with the several cylinders, a superheater mounted between the main boiler and the high-pressure cylinder, a re-heater between the high-pressure cylinder and the intermediate cylinder, a re-heater mounted between the intermediate cylinder and the low-pressure cylinder, and pipes connecting the several superheaters and re-heaters with their respective cylinders. There are seven claims.

976,144. HYDRAULIC CAP MECHANISM FOR SUGAR-CANE MILLS, *J. I. Boyer, Reading, Pa., assignor to Reading Iron Company, Reading, Pa., a Corporation of Pennsylvania.—Filed April 7th*, 1909.

A hydraulic press cylinder open at both ends is formed in the housing. In this is fitted a plunger bearing on the top brass.



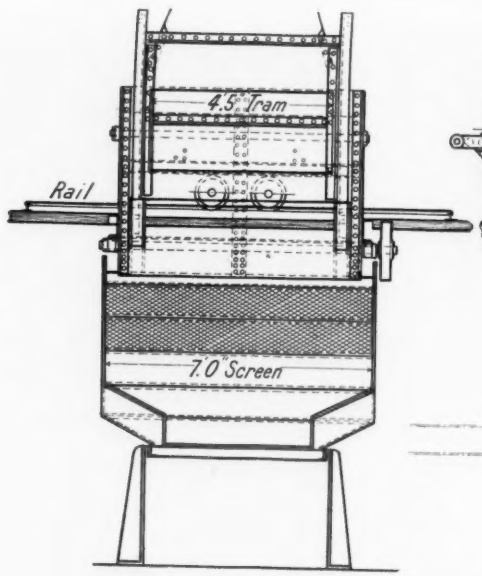
The upper end of the cylinder is stopped by a suitably cup leathered plug, which is secured in place by lug engaging ears as shown. There is only one claim.

ROENTGEN SOCIETY.—An ordinary general meeting will be held on Thursday, January 5th, 1911, at 20, Hanover-square, at 8.15 p.m. A paper by Professor Rutherford on "The Radio-activity of Thorium" will be read.

Fig. 13.

Fig. 6.

Fig. 7.



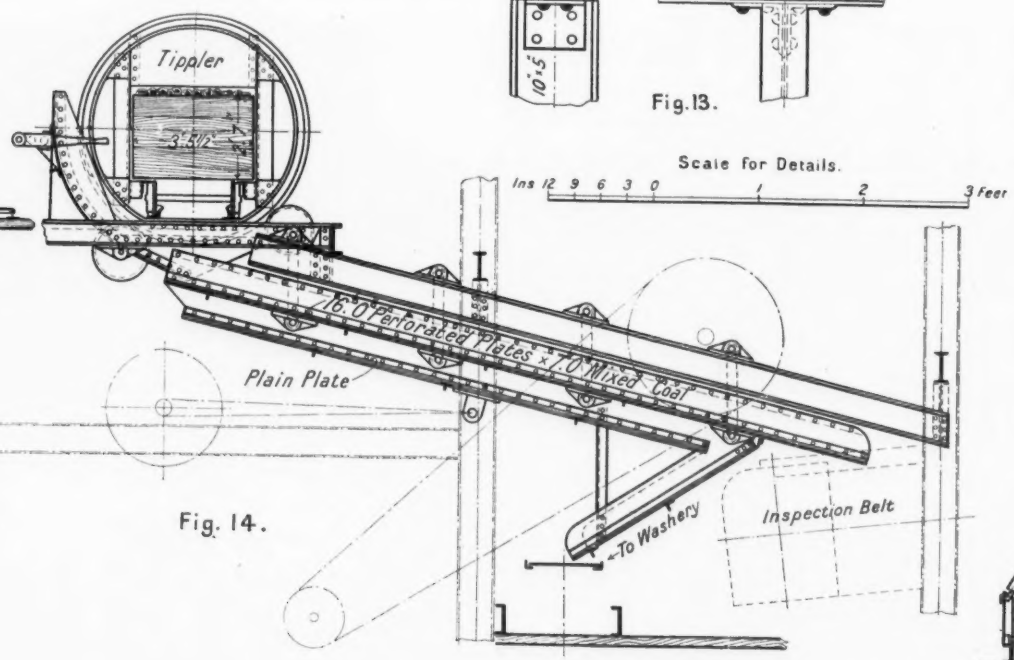


Fig. 14.

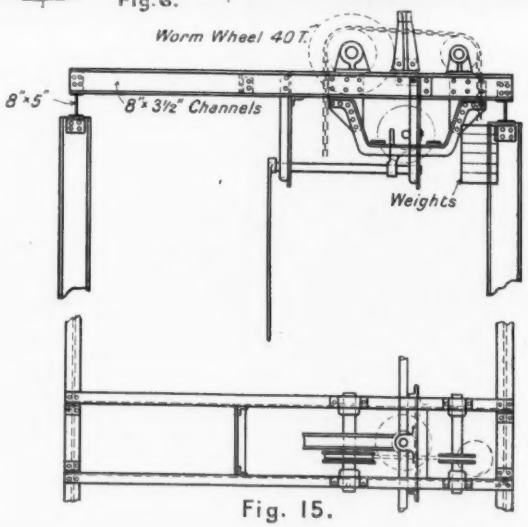


Fig. 15.

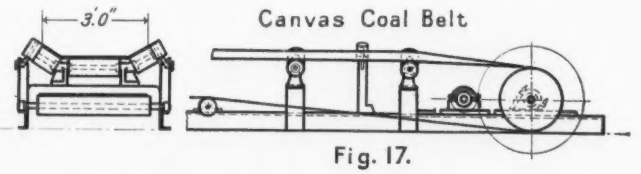


Fig. 17.

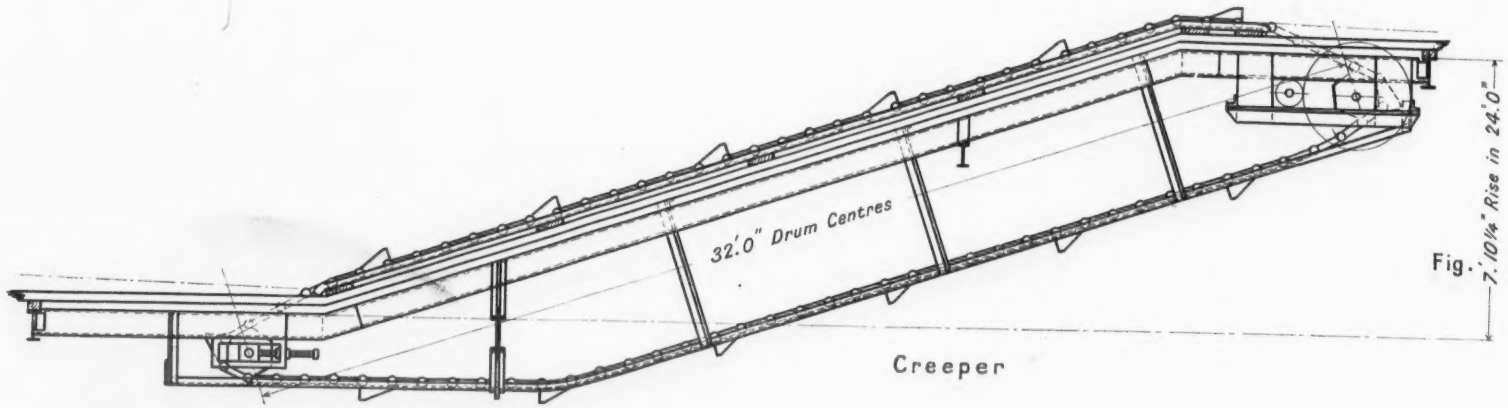


Fig. 16.

Section

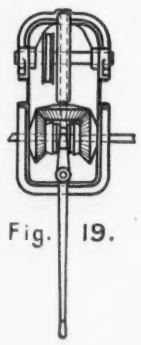


Fig. 19.

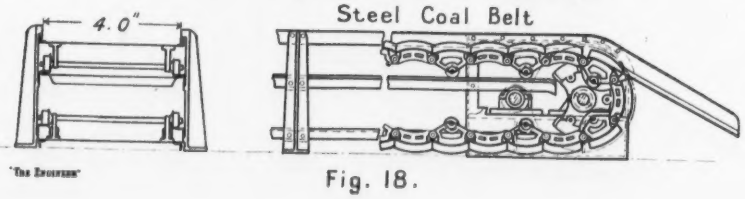
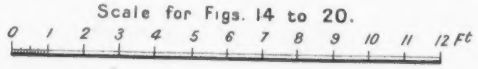


Fig. 18.



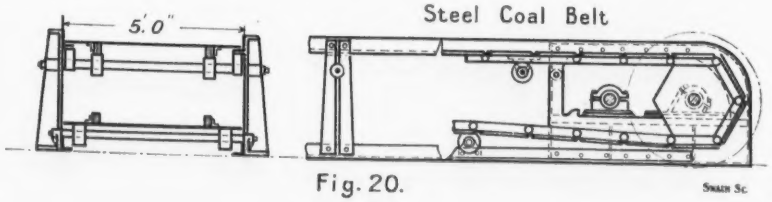
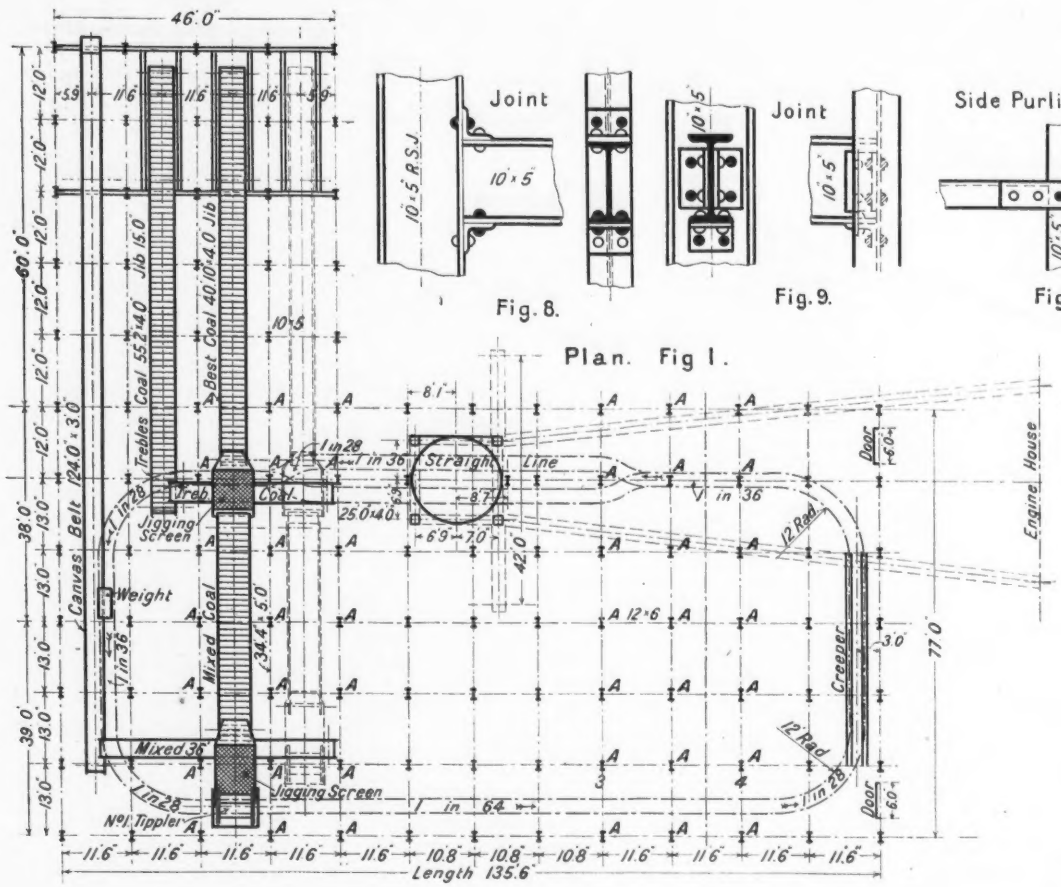


Fig. 20.

A COLLIERY SCREENING PLANT

(For description see page 675)



Plan. Fig 1.

Fig. 8.

Fig. 9.

Fig. 10.

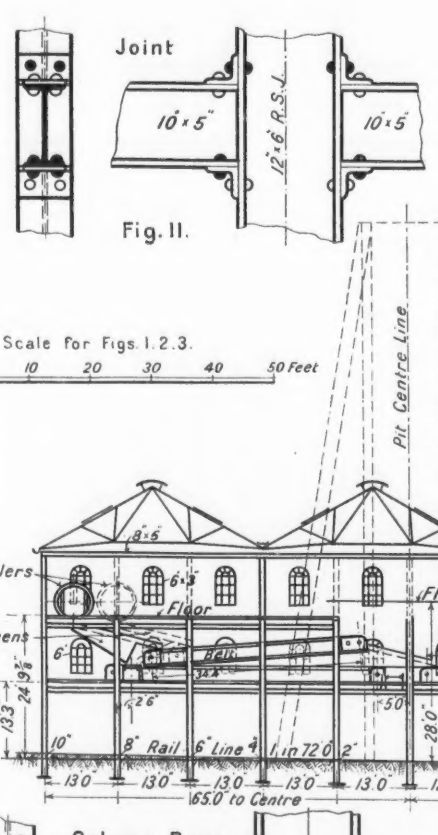


Fig. 11.

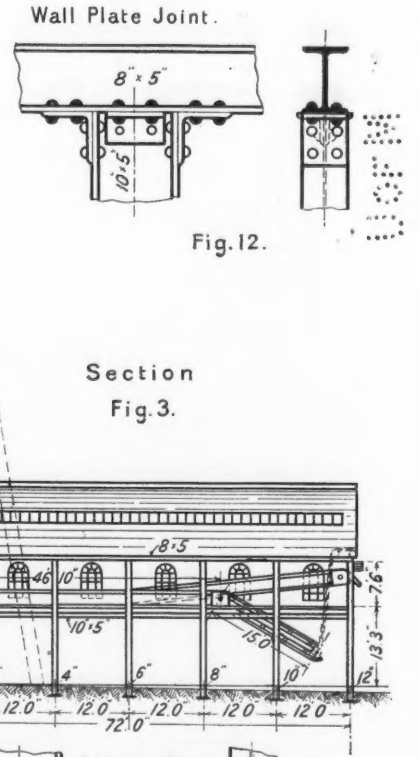
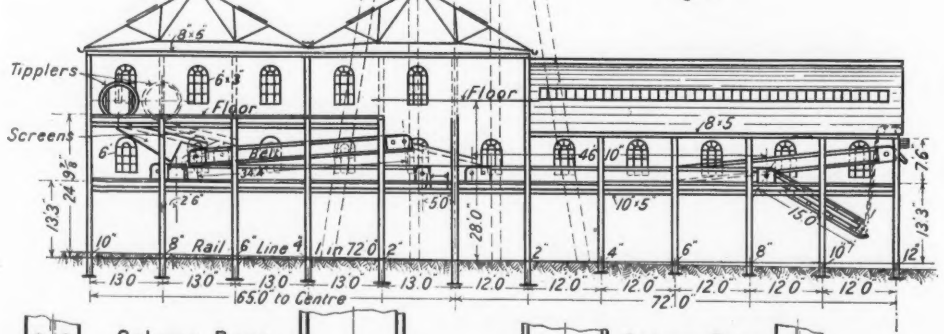


Fig. 12.

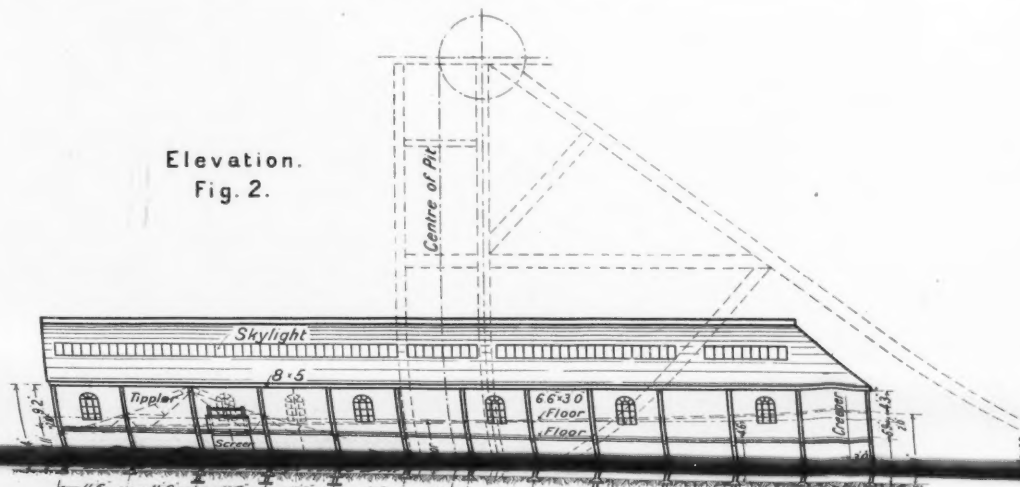
Scale for Figs. 1. 2. 3.

10 5 0 10 20 30 40 50 Feet

Section
Fig. 3.



Elevation.
Fig. 2.



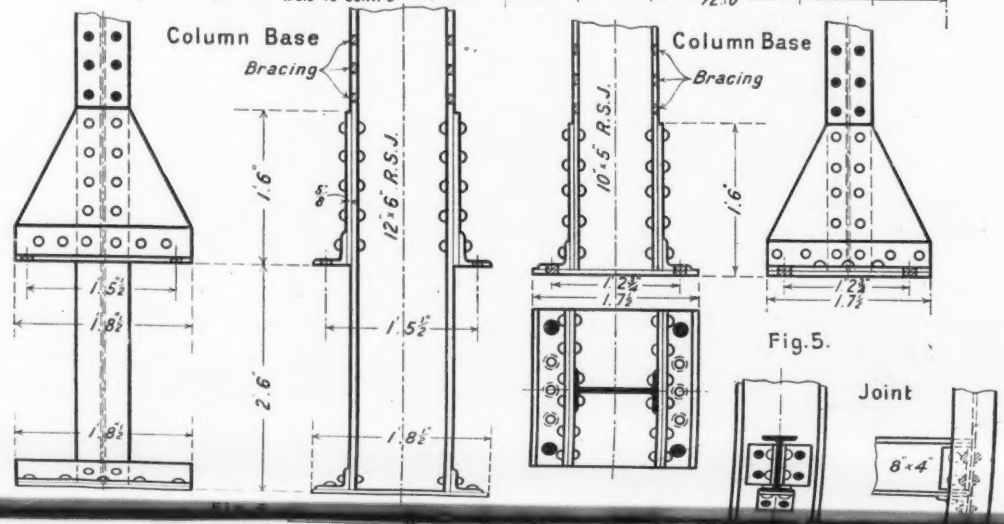


Fig. 5.

Fig. 7.

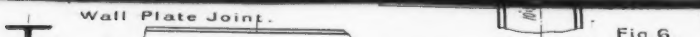


Fig. 6.

NOLIN

THE INFLUENCE OF FORM OF BLADES IN CENTRIFUGAL PUMPS.

By Professor MAURICE F. FITZGERALD, B.A., M.I. Mech. E., A.M. Inst. C.E.

IT appears to be generally laid down, or supposed to be laid down, that, except with regard to some subsidiary frictional and eddy losses, it suffices that the blade angles at entrance to and exit from the fan or impeller be suitably chosen, and the connecting curve a "fair" one. The analogy of a turbine, for example, may be cited, wherein two such forms of bucket as A and B—Fig. 1—whose

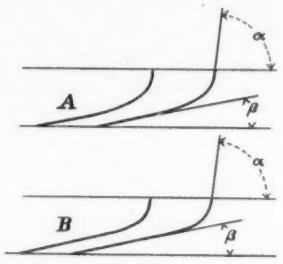


Fig. 1

angles α and β are the same in both, would be considered substantially identical, except as to some possible superiority of A in respect of surface friction, on account of its shortness, and of B in respect of freedom from eddy-making, on account of its length. In the parallel flow case illustrated it is truly enough argued that all parts of the blade move uniformly together at the same speed; consequently, if the supply from the guides is delivered without shock, the bucket may be considered as at rest so far as relative motion of the water in it is concerned. The cases of radial flow turbines and, still more, of centrifugal pumps, differ from this, however, in the circumstance that different parts of the blades move with different linear velocities in circles of different radii, and, therefore, move relatively to one another, as well as to the contained water. This might be easily allowed for if the angular velocity of the water were everywhere the same as that of the bucket, or a constant fraction of it, and though this is not the case, it is usual to make an allowance for centrifugal force on some assumption which virtually amounts to the same thing, based on the blade angles and velocities at entrance to and exit from the fan only, and taking no account of intermediate values. This is really like calculating the area of an indicator diagram from the initial and terminal pressures and volumes, without regard to the law of expansion; and such methods are only suitable when the intermediate values are known to differ little from the terminal ones, or when the area in question is, like the loss due to rounding of corners of a diagram, a small correction, whose precise value does not signify much. In turbines, particularly if the total head be large and radial depth of the buckets small, the centrifugal correction is small, but in centrifugal pumps neither of these conditions is satisfied in many cases. It is, therefore, desirable to point out that there is no particular difficulty in finding the gain of head in the fan of a centrifugal pump by a method which can be applied in graphic form, if desired, and takes proper account of the form of the blades, as follows:—The angular velocity of the pump and the radial and angular velocities of the water are connected at any point with the form of the blade in the well-known diagram of velocities—Fig. 2—

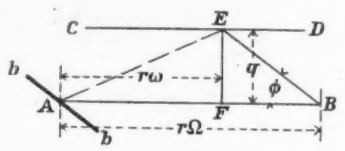


Fig. 2

wherein A B represents the linear velocity $r\Omega$ of a point A at radius r in a blade, part of which is shown as $b\,b$. Let q denote the radial velocity of the water at radius r, and draw C D parallel to A B at a distance q on the velocity scale. Draw B E parallel to $b\,b$ to meet C D in E, and project E down on A B at F. Then A F represents $r\omega$, the linear velocity of the water, at radius r, and its angular velocity is ω, that of the pump itself being Ω. From Fig. 3, showing an ordinary kind of pump in plan

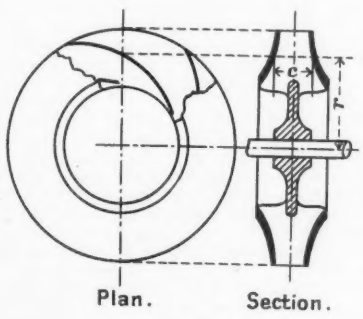


Fig. 3

and section, it appears that, if D be the total discharge, then at any radius r, $D = 2\pi r c q$, wherein c is the depth between checks of the fan at radius r, neglecting an allowance, easily made if accuracy be necessary, for the thickness of the blades, so that the radial velocity q is easily found everywhere, if the section of fan be known and discharge given, and, by means of Fig. 2, applied at a sufficient number of radii, the curve of values of $r\omega$ can be drawn. It differs for different values of q, which is proportional to the discharge, and its ordinates, intermediate between its ends, differ for different forms of blade, though the initial and final blade angles may be the same. Consider now a small block of water in the pump, bounded by two concentric cylinders of radii r and $r + \delta r$, and subtending a small angle $\delta\theta$ at the axis. It is acted on by radial pressures, outward on its inner, inwards on its outer, and slightly inclined to one another on its radial faces. The radial resultant of these per unit length parallel to the axis is $-r\,\delta\theta\,\delta r\dfrac{dp}{dr}$, reckoning outward force positive; and if the weight per unit volume be ρ, and if the block were moving in the circle of radius r, then we should have $-r\,\delta\theta\,\delta r\dfrac{dp}{dr} = -\dfrac{\rho}{g}\,r\,\delta\theta\,\delta r\,r\,\omega^2$, and as $p = \rho h$, where h is head, and $r\,\delta\theta\,\delta r$ divides across, $-g\dfrac{dh}{dr} = -r\,\omega^2$. But as the water is not moving on the circle, there is superposed on this the change of head due to its motion relative to the blade, taken in the ordinary way, so that if V be the velocity B E in Fig. 2,

$$(\text{I.}) \qquad g\frac{dh}{dr} = r\,\omega^2 - \frac{1}{2}\frac{d}{dr}(\text{V}^2).$$

This enables the change of head in the fan to be found either graphically or analytically if the blade form, fan section, discharge, and revolutions be assigned. For by Fig. 2 it appears geometrically that $r\Omega = r\omega - q\operatorname{cotan}\phi$ and $\text{V} = q/\sin\phi$, where ϕ is the blade angle, and as $r\omega^2 = r^2\omega^2/r$ identically, and $1/\sin^2\phi = 1 + \operatorname{cotan}^2\phi$, (I.) becomes, on substitution,

$$(\text{I}a.) \quad g\frac{dh}{dr} = r\Omega^2 - 2\Omega\,q\operatorname{cotan}\phi + \frac{q^2}{r}\operatorname{cotan}^2\phi - \frac{1}{2}\frac{d}{dr}\left[q^2 + q^2\operatorname{cotan}^2\phi\right].$$

If, now, we appropriate H_1 and H_2, R_1 and R_2, V_1 and V_2, Q_1 and Q_2, ϕ_1 and ϕ_2 to the heads, radii, relative velocities, radial velocities, and blade angles at inner and outer radii of the fan respectively, the equation (I.) can be expressed as an integral in two equivalent forms, the first suited best for graphic, and the second for analytical purposes, as follows:—

$$(\text{II.}) \quad g(H_2 - H_1) = \begin{cases} (a) & \text{either } \displaystyle\int_{R_1}^{R_2}(r\omega^2\,dr) + \left(\frac{V_1^2 - V_2^2}{2}\right) \\ (b) & \text{or } \left(\dfrac{R_2^2 - R_1^2}{2}\right)\Omega^2 - 2\Omega\displaystyle\int_{R_1}^{R_2}(q\operatorname{cotan}\phi\,dr) + \displaystyle\int_{R_1}^{R_2}\left(\frac{q^2}{r}\operatorname{cotan}^2\phi\right)dr \end{cases} + \left[\frac{Q_1^2 - Q_2^2}{2} + \frac{1}{2}(Q_1^2\operatorname{cotan}^2\phi_1 - Q_2^2\operatorname{cotan}^2\phi_2)\right]$$

The term in square brackets [ ] in (b) is the same thing as $\left(\dfrac{V_1^2 - V_2^2}{2}\right)$ in (a) written out in terms of Q and cotan ϕ.

It will be observed that in both forms there are terms whose values cannot be found unless the values of q and cotan ϕ are given throughout, as well as terms which depend only on terminal values. The simplest case for analytical purposes is that of a fan with cheeks converging so that q is a constant, say $Q = Q_1 = Q_2$, and blades made to an equiangular spiral so that cotan ϕ = cotan ϕ_1 = cotan ϕ_2 = C a constant, also; V is then a constant also = $V_1 = V_2$ and the second term in (IIa) disappears, as does the corresponding part of (IIb), leaving, on integration,

$$g(H_2 - H_1) = \left(\frac{R_2^2 - R_1^2}{2}\right)\Omega^2 - 2(R_2 - R_1)\,\Omega\,Q\,C + Q^2\,C^2\log_\epsilon\left(\frac{R_2}{R_1}\right).$$

Take, for example, a fan 2ft. diameter, 1ft. eye, depth at edge between cheeks 6in., radial velocity Q 2ft. per second, corresponding to about 2400 gallons per minute discharge, and blades equiangular spirals having cotan $\phi = 2$, that is, ϕ is about 26½ degrees, and find gain of head in the fan at 300 revolutions per minute. After dividing across by g, the figures are $(H_2 - H_1) = 11.56 - 3.9 + 0.35 =$ 8ft. nearly, gain of head. If the spiral be flattened to cotan $\phi = C = 3$, or ϕ = about 18½ degrees, the gain, at the same discharge and revolutions, is reduced to 6.5ft. nearly, and to find the necessary revolutions to gain 8ft., a quadratic for Ω is to be solved which gives about 324 revolutions per minute, for its positive root.

Other examples of analytical integration might be given by choosing, for instance, a fan with parallel cheeks, in which q would vary inversely as the radius, and such a spiral for the blades as would make cotan $\phi = a - \dfrac{B}{r}$, in which a and B are constants, and the angle would vary; but there is no occasion to encumber these columns with mathematical exercises, for but little ingenuity is required to construct expressions for cotan ϕ which lead to no difficulties in integration, and will approach pretty near to most kinds of spirals in use, though the resulting formulæ are lengthy in most cases.

The above example corresponds fairly with a kind of Appold pump, of what may be called commercial type, designed for general utility.

As it is not desirable to design blade forms with special regard to facilities for algebraical manipulation of (II.) in many cases, the following partly graphic method is given, and can be applied to any arbitrary form.

In Fig 4 draw A B horizontal representing, on a convenient scale $R_2\Omega$, the circumferential speed of the outer edge of the disc, and A C vertical, and any scale representing its radius R_2. Join B C; then at any radius r on A C, the horizontal $a\,b$ will represent $r\Omega$, the circumferential speed at that radius, on the velocity scale. From

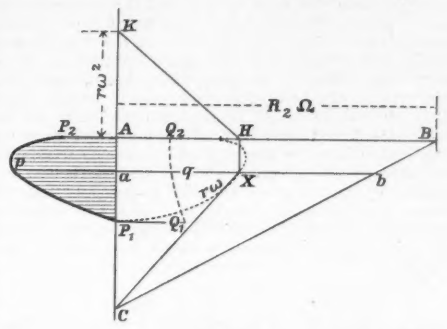


Fig. 4

the plan and section of the pump, find and set off the values of radial velocity at several radii, giving the curve $Q_1\,q\,Q_2$, and by applying Fig. 2 at each, with the proper values of the blade angle and q, draw the curve of $r\omega$. Then to find the integral $\int r\omega^2\,dr$ in (III. a) taking the point marked X in the figure, for example, project X up to H on A B, and draw through H a perpendicular to C X, meeting C A produced in K. Then A K represents $r\omega^2$ on some scale, because the tangent of the angle A C X turns C a ($= r$) into a X ($= r\omega$), and the angle A H K is = A C X, consequently its tangent turns A H ($= r\omega$) into A K ($= r\omega^2$). Consequently, setting off $a\,p$ = A K at a number of points gives a curve $P_1\,p\,P_2$ on the radius as base, whose area, taken by planimeter, is proportional to $\int r\omega^2\,dr$. Supposing the velocity scale to be 20ft. per second to an inch, and the area of the curve to be taken in square inches, the proper factor is $(20)^2$ or 400, to convert square inches into squares of feet per second, and similarly for any other scale. The length scale used for A C is immaterial, and does not affect this factor, provided the velocity scale and planimeter areas are both based on the same unit of length. To find the head corresponding to this part of the whole change, divide its area, multiplied by the proper factor, by g, that is, in the case of the scale above mentioned, each square inch of the curve $P_1\,p\,P_2$ represents 400/32 = 12.5ft. head, and, to find the total amount, $H_2 - H_1$, the value of $\dfrac{V_1^2 - V_2^2}{2\,g}$ has to be added. Observe that the divisor for the area of the curve $P_1\,p\,P_2$ is g, not $2\,g$, which one might expect it to be, on noticing that the area represeuts the square of a velocity.

The graphic method has the defect that if the area of the curve is found for a given value of the discharge and revolutions, the same curve cannot be used to determine the gain of head for other discharges and revolutions, or other discharges at the same revolutions, but only for discharges proportional to the revolutions, which merely imply an alteration of the velocity scale, which affects q, $r\Omega$, and $r\omega$ alike. If, for example, with the same revolutions, a different discharge, say, double that in the figure, were taken, all the ordinates q would be doubled, and those of $r\omega$ would be reduced, but not halved, and those of p would be altered in a complicated way. Analytical formulæ, such as (III.), cover within themselves, so long as they remain in symbols, all such variations, but the labour of calculating and tabulating their values is at least as great as that of drawing the corresponding figures.

In connection with the subject of the influence of blade-form, some general considerations appear worth mentioning. The area of the curve $P_1\,p\,P_2$—Fig. 4—represents, in

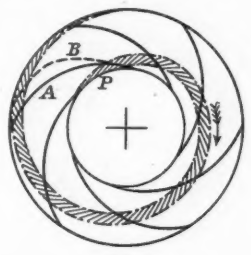


Fig. 5

most cases, the greater part of the gain of head in the fan. If the form of blade A—Fig. 5—be changed without altering the entrance and exit angles to B, all the intermediate values of the blade angle may be increased, and with them the intermediate ordinates of the curve $P_1\,p\,P_2$, with a consequent gain of head in the fan, supposing the discharge and revolutions to remain the same. It would lead too far from the immediate point to discuss in general how this possible gain is limited, but the relative efficiency of effecting a certain gain of head in the fan, by suitable blade-form as compared with seeking to effect the same by a diverging vortex casing is worth considering. In Fig. 5, taken as representing, with blade A, the 24in. fan of the numerical example, the absolute form of the stream of water entering at P between a pair of blades and passing through the fan is shown shaded. With form B, it would

not be much changed in general appearance, except that it would reach a little farther round the circle. If this stream tube were a freely discharging nozzle, there would be a difference of head at its ends fixed by the velocities there; but the actual difference is quite another thing, because the nozzle is cut up into compartments by the blades which cross it, and act like pistons driving the blocks of water between them. This nozzle is continued, or may be continued, in a vortex or spiral casing, outside the fan; and, if this be an expanding nozzle, pressure will be gained in it, but it is well known that there is a kind of instability of the flow in such nozzles, which leads to broken and discontinuous motion being very difficult to prevent in them, and their efficiency is apt to be poor, whereas it would appear likely that there would be far less opportunity for the development and spreading of such discontinuous and turbulent motions in the part of the nozzle within the fan, than in the casing. The way water behaves in expanding nozzles gives one the impression that the several small stream tubes of the jet are in some way analogous to long columns in compression, and crumple up with very small pressures, unless kept as straight as possible.

THE DESIGN OF SCREENING PLANTS FOR OLD AND MODERN COLLIERIES.

By J. S. BARNES.

No. II.*

For any given tonnage to be screened and sorted in a given time, it is essential to determine the size and carrying capacity of the trams, and the number of trams requisite per unit time to deal with the output. If we determine on using a tram as large as possible, consistent with the mine workings and roads, and if the coal or other mineral is sufficiently hard and strong to allow of it being packed or boarded above the tram top, then we obtain a maximum output per tram, which is of great importance in fixing upon the size and number of the tipplers and screens. For it is evident that the number of revolutions of a tippler must be limited to a certain quantity in a given time, if we wish to have a minimum of breakage of the coal, and therefore small trams should, where possible, be avoided. Of course we should have a larger width of screen and conveying belt to deal effectively with a maximum tonnage tipped per tram on to the screen, together with all the parts and motive power relatively stronger and higher, than when we use a smaller tram, but we obtain very important advantages in obviating a multiplicity of tram roads, tipplers, and screens. In addition, repairs, maintenance and labour are reduced considerably, and it is unnecessary to run the machinery at a high speed, thus considerably affecting the life of the plant.

If the seam of coal or other mineral is all one kind, undue complications are avoided when making out the designs. On the other hand, when dealing with more than one kind of mineral from one or more seams, we are confronted with certain problems, which can only be solved in each particular colliery on the site, and arrangements have to be made with the various kinds to suit local requirements. For instance, a seam of coal having two sorts, say, hard and soft in equal proportion, requires to be filled into separate trams at the coal face, and provision will have to be made for separate screens, tipplers and conveying belts, to treat each kind separately. If we have two separate seams of different quality coming from one shaft, the above conditions apply, and we may arrange the plants contiguously so that one set of men and boys may deal with both kinds. This means a plant of double the capacity of that required when the output is of one kind of mineral. We may, as an alternative to the above, arrange for the various kinds of coal to be filled into separate trams, and these to be directed into their proper distinct storage roads. It will be then possible to wind one kind at a time and get it screened and sorted, before allowing the other sorts to be wound. Otherwise this storage may to a certain extent be made on the surface. We thus avoid the double capacity plant, but at the same time somewhat complicate other matters, such as the sidings. Delay and stoppage of the pit may, in fact, often be caused by this arrangement. On the whole, if the tonnage is to exceed 1,500 tons of each kind, or from each seam, it is advantageous to erect separate plants for each kind, and, if possible, all in one building. The capital expenditure becomes, of course, a serious item in such screening plants, and the writer has designed and set out several installations as a compromise where both systems were adopted. In some instances, from £10,000 to £12,000 have been spent on a double capacity screening plant capable of dealing with an output of 3,000 tons a day. Against this must be set the cost of making extra storage space, the increased labour entailed in shunting the wagons and trams, the loss accruing from the trams, etc., standing idle when they might be running, thus involving an extra outlay for a given output, and the great inconvenience to the miners in having to set aside one kind of mineral for a certain time.

The number and sizes of the various sorts of coal is controlled by the state of the markets, but provision should be made for dealing with several sorts and sizes at quick notice. The number of sorts will determine the number of conveying belts and screen plates to employ. These plates should be arranged to be readily changeable so as to obtain different sizes of coal. The number of conveying belts, however, taking the coal from a screen frame cannot readily be altered. The size of coal screened also depends somewhat upon the nature of the coal, its friability being important in this respect. A good practice is to arrange the plant so as to turn out bests, that is, all pieces above 3 or 4 cubic inches; then trebles, pieces between 3in. or 4in., and 1¼in. to 1¾in.; nuts, 1¼in. to ¾in. or ¾in. cube; beans, ⅞in. to ⅜in. cube; peas, ⅜in. to $\frac{1}{16}$in., and smudge or duff, $\frac{1}{16}$in. to fine grains. If this has to be done on one screen, we require four perforated plates, and one dead-bottom plate. This means a very deep screen, for since it is desirable to be able readily to change any perforated plate, the distance between any two must be not less than 12in. to 15in., so as to permit of a man's getting between them. It is therefore much more desirable to have more than one screen for these sizes, thus reducing the weight of the plant. For the large sizes, it is preferable to have jigging screens where the coal is not friable, and revolving screens for the smaller sizes. The jigging screens should be arranged to have sufficient throw so as effectively to screen the coal, but at the same time we should bear in mind that the greater the speed or number of jiggs, the greater will be the vibration set up all over the structure. If the travel of a jigging screen is large, say, 6in. to 8in., then it should have a correspondingly slow speed, or small number of jiggs per minute. On the other hand, if the throw is small, say, two or three inches, the number of jiggs made per minute will have to be moderately high, so as to screen the coal properly. If we use a throw of 6in., and 160 jiggs per minute, then for the same screening effect, with a stroke of three inches, the number of jiggs should be 320. Or, expressing it mathematically, we may say that if L equals length of throw, and N equals number of jiggs per minute, then L, multiplied by N, equals constant. The writer has made a close observation of this effect, by designing a variable throw eccentric and noting the screening effect. It can be taken generally that, the greater the number of jiggs, the more complete will be the screening effect. This is obvious, when we consider that the movement of the mineral during the period of a stroke is practically nothing, but that the movement takes place at the point of reversal of the stroke. Consequently the greatest possible number of jiggs, compatible with efficient bearing speed, should be aimed at when designing the screens.

If the coal is damp, the inclination of the screens must be greater than when it is dry, and in any case the angle should be sufficient to allow the mineral to pass slowly over the screen. A good rule is to set the screens at an inclination of 1 in 3.5 to 1 in 4 for dry coals or ironstone. If the percentage of small is great, or the mineral damp, it is necessary to increase the inclination to 1 in 2.14, or 1 in 3. These inclinations have been found by the writer to give good results in the Lancashire, Yorkshire, Durham, and Nottinghamshire districts.

The width of the screen depends chiefly upon the capacity and length of the trams. If the screen is at right angles to the direction of the conveying belts, its length will depend upon the number of these, and in this case the screen may become exceptionally long and heavy, and the vibration set up, consequently very great. In some designs bars are used in the screens in place of perforated plates, but this practice is not to be recommended, as long thin slabs of mineral may readily pass through into the smaller sizes below. Fixed screens have the advantage of not requiring any power, but owing to the great inclination at which they must be set—about 30 degrees—the mineral quickly passes over them, and consequently does not get efficiently screened. For this reason this class of screen should be avoided where possible. With regard to the revolving screen, an important advantage possessed by it is the absence of the vibration set up by a jigging screen. On the other hand, the coal is liable to be churned, whereby breakage is caused. With this type the inclination should be on similar lines to that of the jigging screen. Where the revolving screen is parallel throughout, it must be supported in a thrust bearing at its lower end. This may be avoided by making the barrel of the screen in the form of a cone.

The revolving form of tippler is preferable to the end type, and should be designed so as to allow the tram easily to enter and leave it in the shortest possible time. If properly driven, it should discharge the coal slowly on to the screen, so as not to scatter some of it too far down the plates, where the screening effect is small. When all the coal has been tipped from the tram, the tippler should then revolve quickly so as to economise time in bringing back the empty tram. If provision is made for the tippler to stop automatically, much time will be saved, and accidents avoided, and it is also advisable to make arrangements for spreading the mineral well over the whole width of the screen. To avoid slipping of the tippler it should be provided with spur wheel and pinion, and in addition, less wear will thus take place on the friction cones and rings. Provision is sometimes made for the the empty tram to be knocked through the tippler by the next full one, and the tippler automatically started by the empty tram relieving a catch.

The kind of conveying belt to adopt somewhat depends upon the nature of the coal, and we see examples in steel, canvas and rubber at work at some collieries. In all cases some provision should be made for the best or large coal to be discharged gently from the screen on to the belt, and to secure an even distribution and continuous supply of the coal over the entire width of the belt. This can be effected by a swing door arrangement or a secondary short conveying belt feeding the main picking belt. Otherwise a shute may be interposed between the screen and the conveying belt. If the coal is very clean, only short conveying belts are required, but for a seam having dirt to be sorted out—and this sometimes adheres firmly to the coal—long belts travelling at slow speeds are necessary, so as to enable the dirt to be removed. The width of the conveying belt depends somewhat upon the speed and the tonnage passing over it in a given time, and for a cleaning belt, a good practice is to adopt one of from 4ft. to 5ft. in width. If the picking belt exceeds this width, it is difficult for the boys engaged in cleaning out the dirt to reach into the centre of the belt. The height from the floor line to the belt top should not exceed 2ft. to 2ft. 6in. If the coal is hard or very dirty, it is much better to have steel plate conveying belts, as they are not so liable to become damaged, but for a friable clean coal, canvas or rubber belts are most suitable. A vital point in favour of canvas or rubber belts, is that the risk of breakage is reduced to a minimum; but on the other hand the edges of such belts are apt to be considerably worn, if proper arrangements are not provided to preserve them. It is good practice to arrange, where possible, the conveying belts for the large sizes parallel with the length of the screen, as when the conveying belts are at right angles to the screen length, the reversal of the motion of the coal dropping on to the conveyor tends to break it. At the delivery end of the conveying belts, provision should be made for delivering the coal into the wagons by means of a swing jib, and thus prevent breakage of the coal. This, if neglected, may cause the coal to be broken to such an extent that it will not be saleable at its proper value.

The method of transit of the trams to and from the cages requires special attention, so as to avoid undue expense in this portion of the work. A good practice is to arrange the structure so that it has various gradients suitable to the tram loads. These gradients should, where possible, be on the descent from the full tram side of the cage to the weigh bridge and tipplers, and should be made steeper round the curves than on the straight portion. The proper gradient can only be determined from experiment with the proposed trams and an experimental road. However we may try to calculate the proper gradient, we shall find our figures in error on account of the varying friction, and the temperature effects on the grease of the axles. This is very important, as when once a screening house is erected, and the gradients settled, it is practically impossible to alter them without disorganising the whole arrangement. The little extra cost of the experimental work should therefore not be objected to. At some of our most recently designed collieries, the full trams are elevated up to the weigh-bridge and tipplers, the empty trams gravitating back to the cages. This is bad practice. It is obvious that the power required to elevate the full tram is very great in comparison with that required in the reverse method, and that the life and reliability of the hauling gear is considerably diminished. Where possible, therefore, the full trams should gravitate to the tipplers, and not the reverse.

The general arrangement of the plant and structure can now be approached by making out a few different general drawing arrangements, and looking into the comparative advantages and disadvantages of each system. When the main screen is at right angles to the sidings, we save the expense of the cross conveying belts, but on the other hand require exceptionally strongly-built screens. In this way serious vibrations are set up, so that a heavier design of building and screen supports becomes necessary. On the whole, therefore, the difference between the cost of cross-belts—which are essential when we arrange the screen parallel with the sidings—and that entailed in the installation of screens at right angles to the siding, is not very much. In fact, the writer has had estimates, in which the cost of the heavy screens at right angles to the railway sidings, together with the heavier structure, exceeded the cost of the screens, cross belts and lighter structure of the optional design. It is good practice to arrange jigging screens in two sets in one line, and parallel with the railway siding. By so doing the vibrations of one set can be made to damp those of the other with a considerable diminution in both. The width of the building and the kind of structure to adopt, are somewhat regulated by the number of sorts of coal screened. Sometimes timber and brick pier wall structures are erected, but both kinds take up considerably more space than a steel structure. The timber work is liable to catch fire, and the brick piers are liable to crack, while the space required for a brick pier wall is very large in comparison with what is required with either steel or timber. Owing to the height at which pier walls are built, they require to be about 4ft. to 5ft. thick at the rail level. If tapered off and arched, economy is effected; but in any way the cost is considerably greater for this kind of building. Whatever kind of building is adopted, the space between the side of the building and the wagons should be not less than 18in., and preferably 2ft., otherwise accidents are sure to happen. One can see this important item neglected at some modern collieries, where also a common practice is to erect columns or steel girders with the flanges parallel with the railway lines. Both of these features reflect seriously on those responsible for the design, and the writer believes that an Act of Parliament should be passed stipulating a minimum clearance between the wagon sides, and prohibiting the latter practice. The web of the steel stanchions should always be parallel with the railway.

The height of the building is made to suit the screens and gradients adopted. The clearance between the wagon tops and the first floor should be ample, to allow room for a man on the top of a full wagon. The conveying belt floor need not be so high as the tippler floor, and in fact it would be very bad practice to have it so. When deciding the heights, it is customary to commence at the conveying belt line, and from this point set out the angle and outline length of the screen, fix the position of the tippler

* No I. appeared December 23rd.

centre, and then work out the gradients from this point to the cages. Ample headroom and good lights should be provided for by means of skylights. Cast iron columns should not be employed, rolled steel joists being preferable, as being more durable and permitting better connections and joints to be made. A complete system of bracing should be used, preferably of Tee sections, and should be arranged to reduce vibrations, and take a portion of the stress at the main joints. Corrugated steel sheeting for the sides and roof of these structures forms a suitable covering. It is good practice to cover all the floors with chequered steel plates, but this adds very considerably to the cost, and timber boards of 11in. by 3in. make a firm, substantial, but not fireproof, flooring.

The foundations should preferably be made of concrete, and sufficiently extensive to have the stress on them not greater than three to four tons per square foot. In the direction of the siding lengths, the foundations should preferably be stepped from column to column so that the feet of the columns lie below the rail level. The sidings about the screens should be arranged to have a gradient of 1 in 60 to 1 in 70, so that the trucks move easily when the roads are dirty, or in frosty weather. It is a great mistake to try to load more than one sort of coal on to one wagon road. If the seam is a dirty one, provision should be made for either a spare wagon road, or a tip, to which the dirt can be conveyed.

If there is any possibility of a larger output being required at some future date, or of more conveying belts being installed, the building should be arranged so that extensions can be readily made. The position of the screens, it has lately been recommended, should be a good distance from the pit shaft mouth, and no doubt where the coal is dry and dusty this is a good practice; but where the coal is damp or wet and not dusty, it is useless to move the screen building away from the shaft more than possible, except in the case of timber structures, which, if catching fire, might cause fumes and smoke to get into the mine. No doubt the most economical method of driving the various machines is by means of electricity, and much can be said on this point which would take up too much space in an article of this description. It is desirable to have one motor driving each individual belt or screen, so that the speed of any belt, tippler, or screen can be regulated independently of its neighbours.

NEW WATER SUPPLY FOR AUCKLAND, NEW ZEALAND.

FOR some thirty years the city of Auckland, New Zealand, has been provided with water from springs taking their rise in a volcanic watershed situated about three miles from the city. The supply necessitates pumping. Of late years the population has increased considerably—there not now being far short of 100,000 inhabitants in the water area—and it was found necessary to seek another source from which to obtain additional water. In 1903 Mr. Hugh Munro Wilson, of Auckland, was entrusted with the work of surveying a source and with the developing and carrying out of a gravitation scheme. He chose a site in the Waitakerei ranges, which lie about 17 miles due west of the city—see Fig. 1. These ranges are densely wooded and are practically virgin country. They have an elevation in places of 1100ft. above sea level, and have several good streams which are fed by an almost continuous rainfall for six months in the year. After careful investigation and repeated gauging of the flow in various creeks, it was decided to tap the Waitakerei stream at a point immediately at the head of the celebrated Waitakerei Falls, which have a sheer drop of 300ft. into an enormous basin eroded out by the stream in the course of countless ages, in a cleft in the conglomerate formation that constitutes the basis of these ranges. To gain access to the site it was necessary to cut a

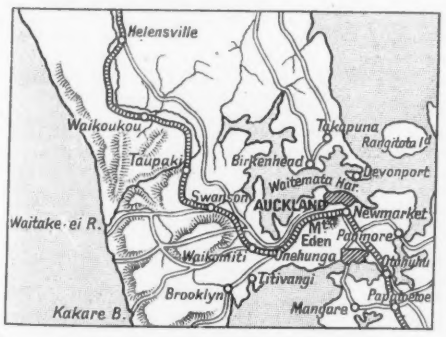


FIG. 1—WATER SUPPLY OF AUCKLAND—MAP

road along the side of one of the spurs for half a mile to get to the main range, through which a tunnel, 7ft. by 7ft., was driven half a mile in length. From the west end of this tunnel another mile of track, 10ft. wide, was cut along the almost perpendicular side of the mountain; this terminates at the head of the Falls, and at the site of the impounding dam. This work included four miles of ordinary bush road construction beginning at Swanson railway station, 1½ miles of mountain side cutting, one tunnel ½ mile long, and another tunnel 200ft. long; a total of, say, 6 miles. Along this a 2ft. 6in. gauge tramway was laid from the railway station to the head of the Falls. The work was done partly by the city council and partly by the contractor for the concrete impounding dam, and the road was employed for hauling all materials. Horse traction was used, the gradients rendering steam impracticable.

It is not proposed to give details of all the various works, as they do not contain any unusual features, and we shall confine ourselves to the construction of the great concrete dam, which is the largest by far at the present time in New Zealand. Briefly stated, however, the various works embraced in the scheme, including those already mentioned, were as follows:—(1) Four miles of bush road formation from Swanson railway station. (2) 1¾ miles of graded track through the Foot Hills to take the 27in. diameter locking bar pipe main from the break pressure reservoir in the open country. (3) The formation of a half a mile of mountain side cutting, 10ft. wide, on the east side of the mountain. (4) The tunnel, 7ft. by 7ft., through the main range and half a mile long. (5) The formation of one mile of mountain side cutting, 10ft. wide, along the west side of the mountain, including a tunnel 200ft. long 7ft. by 7ft. (6) The clearing of 66 areas of bush in the impounding area. (7) The construction of a break pressure reservoir on the Foot Hills at the east side of the range. (8) The construction of the concrete impounding dam. Each of these items, as given above, constituted separate contracts. The break pressure reservoir is of concrete with a principal roof, and has a capacity of 1,000,000 gallons. Its top water level is at an elevation of 470.30ft. The main tunnel offered no particular engineering difficulties. It went through solid ground composed of hard conglomerate and sandstone rock; it was practically dry throughout, and no timbering was required. The approximate cost was 30s. per lineal foot. The clearing of the impounding area was remarkable only for the enormous quantity of bush that had to be removed. This ranged from Kauri trees, 9ft. in diameter, down to the almost impenetrable undergrowth that covered every square foot of the 66 acres. All this was grubbed 6in. below the surface, and the whole area on completion was absolutely void of vegetation. The cost of this work, including the cutting up of 90,000 super feet of the timber for construction purposes, was a little over £4000.

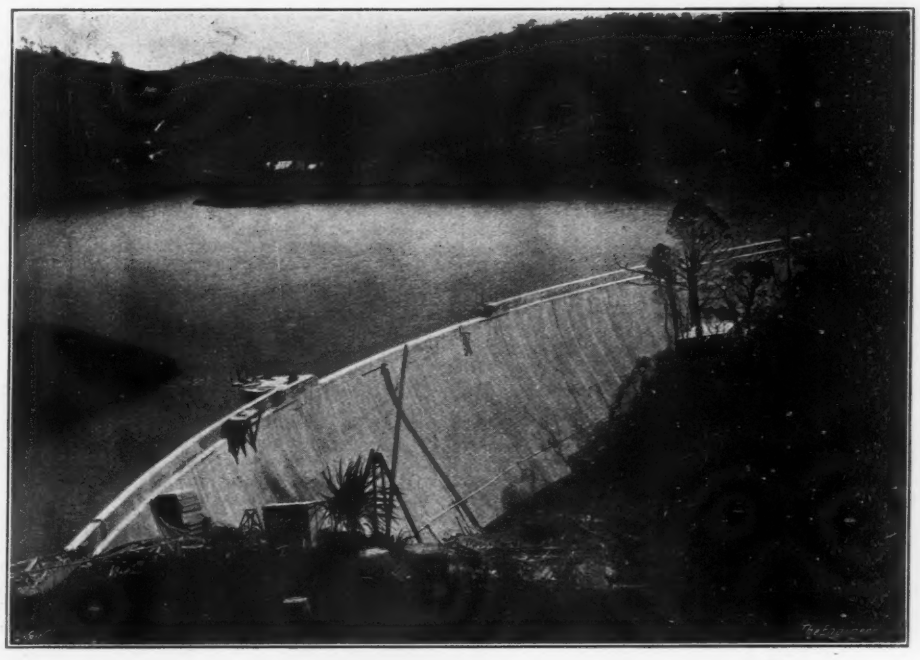


FIG. 2—DOWN-STREAM FACE OF DAM

The site chosen for the concrete impounding dam is admirable. It is so situated that it impounds every gallon of water discharged by no less than six different creeks or streams draining an area of about 3000 acres. In June, 1905, a start was made to clear the bush from the site in order to define the exact position of the dam. It was then found that it would have to be where two converging spurs were cut through by the stream, and to utilise these spurs for abutments a curved dam was decided upon, as a straight dam would have cut both spurs obliquely. A series of six trial shafts were then put down, some of which—those in the spurs—bottomed on to a fine hard conglomerate rock, while three near the stream bottomed on to a sandstone formation. This led to the conclusion that the conglomerate overlayed the sandstone, as those that bottomed on the latter were much deeper than the others. All trial shafts exposed an area of not less than 25 square feet.

In designing the work Mr. Munro Wilson decided to adhere to a gravity section, notwithstanding the additional strength gained by the curvature form, as a guard against earthquake shock. The curve is to a 382ft. radius, and the total length at top water level is 533ft. The lowest foundation is at level 602.41ft. in the bed of the creek, and it rises gradually, and practically uniformly, to 642.00ft. at the east end, and 642.50ft. at the west end. The top water level was originally fixed at 666.50ft., but was afterwards raised to 668.50ft. The foot of the parapet is 671.50ft., and the latter is terraced at the ends to 673.50ft., thus giving a total height of 71.09ft. from lowest foundation level to the top of the parapet. The up-stream face batters ⅜in. to the foot, and the down-stream face 8in. to the foot up to the 649.50ft. level, from which point the up-stream face graduates to a vertical at the 668.50ft. level, and the down-stream side curves at a tangent and gives a crest top width of 3.50ft. The parapets are 3ft. high and 2ft. thick, and an overflow weir, 100ft. long, has been left in the centre.

The water is drawn off by a vertical 20in. cast iron pipe column standing in a semi-circular chamber on the up-stream side; within this chamber are assembled all the valves, which draw the water at three different levels. The bottom draw-off is at 618.87ft., or 49.63ft. below top water level. The intermediate valve is at 634.42ft., and the top valve at 653.25ft. In all cases the water passes through a ¼in. mesh strainer. These strainers rest on a bell-mouth, and are free. They can be drawn up by a winch for cleaning purposes, the arrangement of gear being such that they will descend into their places accurately. The approximate content of the storage reservoir is 290,000,000 gallons, and the submerged area is approximately 50 acres. It was intended originally to build the work by day labour, but it was afterwards decided to let it by contract, and a tender at a little under £30,000 was accepted, and the contractor started work in August, 1906.

The total quantity of excavation in the foundations was approximately 7000 cubic yards. The conclusion that the conglomerate overlay the sandstone proved erroneous; when the full trench was opened out the sandstone referred to in the trial shafts proved to be a band, the full width of the trench, lying on the conglomerate. This was taken out, and an excellent foundation throughout, with a gradual slope up-stream, was obtained. This was washed with a nozzle under a pressure of 45 lb. per square inch, tapped with a 14 lb. hammer, and all flaky patches removed. The excavation was in a bastard conglomerate, and stood splendidly with vertical trimmed sides without timbering, the depth in places being 28ft.

The concrete was of two kinds, numbered 1 and 2. The latter was used only on the up-stream face, where it was 6in. in thickness. No. 1 was used throughout the remainder of the structure. No. 1 concrete was composed of 18 cubic feet of 1¼in. metal, 9 cubic feet of ¾in. metal, 11 cubic feet of sand, 4½ cubic feet of cement. No. 2 was composed of 18 cubic feet of ¾in. "shivers," 11 cubic feet of sand, 4½ cubic feet of cement.

All concrete was mixed by hand in cubic yard batches, and in the following manner:—The whole of the materials were gauged in cubical boxes. The sand and cement were first mixed together by being turned twice dry. The metal was spread 6in. thick, the "shivers" were equally spread over it, and the whole was covered by the combined sand and cement. The mass was then turned twice dry. Water as required was added during the third and fourth turns, and the whole then received two final turns; six turns in all. Owing to stone "plums" being used, the water was to a certain extent forced out of the concrete again; therefore the quantity of water used per batch continually varied, as some batches had to act as an absorbent to prevent loss of matrix; for this reason Mr. Munro Wilson preferred hand to machine mixing, as the constantly varying conditions were more under control.

Before laying the concrete the portion of foundation to be covered was, as explained above, washed by nozzle under 45 lb. pressure per square inch, and made absolutely clean. Upon the surface so obtained a thick coat of pure cement grout was laid, and heavily crushed into the rock surface, and upon this was laid a half-inch coat of 2 to 1 cement mortar, and the concrete was placed immediately upon that.

The No. 1 and No. 2 concrete mixtures were placed in position at the same time, and well rammed together. Stone "plums," with a minimum size of 1 cubic foot in every direction, were inserted, 12in. back from the up-stream face above all foundations, and 9in. back from the down-stream face. The stones were washed under pressure before using, and were well ground down into the concrete, which was used very wet, and practically flowed round the stones till they were covered to the requisite

depth; upon which another layer of stones were bedded. Spading and ramming were kept continuous. No concrete was tipped from barrows into place, but was placed by shovel from a small bunker at the face.

The whole work was built in courses 3ft. high, accurately levelled and kept continuous till the course was completed from end to end. All the concrete, when in place, was covered with bags kept constantly wet for four days, and after the bags were removed the set concrete was kept constantly wet by hosing till the succeeding course covered it. All concrete surfaces were washed under the usual pressure, and well grouted. This system of building was specified throughout, and was continued up to the 654.50ft. level. The contractor then requested to be allowed to substitute mass concrete owing to the want of room. This was assented to, and the work was completed with the No. 1 concrete in mass laid in 6in. layers, and tipped from the barrow.

There were 160ft. of the east end, and 190ft. of the west end of the dam in trench, which receded to 40ft. at each end at the top of dam. The up-stream side of the trench was dressed neatly and vertical, and against this surface, after being well washed and covered with a thick coat of neat cement grout, the concrete was laid and well rammed into the surface, no timbering being used. At the ends, and also 30ft. from the ends, chambers were cut into the bank 4ft. by 3ft. These were prepared, as was the rest of the face, and filled with concrete. They were cut out from the bottom upward for each 3ft. course, the continuous line of trench and concrete being thus broken. These chamber locks started at the foundation and continued to 2ft. above top water level. The top of the dam was finished off with 4in. and 1½in. nozings, and all horizontal surfaces were covered with ¾in. 2 to 1 cement rendering. This was the only rendering on the whole work, the remaining concrete from bottom to top being left as stripped from the moulding boards.

The method of construction, as detailed above, has, we understand, proved perfectly satisfactory. The dam is stated to be absolutely watertight, there not being a sign of moisture on the down-stream face, nor over the inside of the valve chamber, the wall of which, though only of an average thickness of 3ft. 9in., being absolutely dry with 40ft. of water against it at the present time.

The approximate quantities of materials used in the dam are as under:—

15,500	cubic yards	total	
14,103	,,	,,	mixed concrete
1,397	,,	,,	stone plums
5,758	,,	,,	sand
30,300	bags of	cement	
9,169	cubic yards of	1½in.	metal
4,992	,, ,,	¾in.	metal

The whole of the sand used was brought from the Kaipara Ocean beaches, and although almost the whole of it had to be screened to take out coarse foreign matter, it was otherwise clean and of good quality. The cement used was exclusively Wilson's two Star Portland of local manufacture, and it proved itself admirably adapted for this class of work, it having comparatively slow initial setting properties which suited the conditions of work better than a quick-setting cement would have done. The stone used was a blue basalt, weighing about 155 lb. per cubic foot. It is evidently a volcanic flow and, so far as is known, is the only stone of its kind in the Waitakerei Ranges. The quarry is situated at the west end of the main tunnel, and, owing to its great height, was very expensive to work. The face on completion of the work, including a heavy coat of top stripping, was 120ft. high from quarry floor level. It is one mile from the dam. The crushing plant was also erected there. The contractor's plant consisted of two stone crushers, together capable of making 60 cubic yards per day. The stone was gauged by a revolving screen driven by a belt from the big crusher; the rejects passed from the screen into the smaller crusher, and were made into shivers.

A 3-ton steam crane was installed to lift the concrete and other materials from the concrete-mixing platform to the wall level. The platform could not be laid higher than the 622ft. level, the country being so precipitous. When in full swing the contractor had as many as twenty-two horses at work hauling sand and cement from Swanson station. An efficient gravitation water supply for construction purposes was installed at an elevation of 770ft., thus giving 100ft. head over the top of the dam. The distance through which the supply was brought was 2500ft. and 2in. and 3in. pipes were used to the works. A complete system of taps, &c., was well arranged for all purposes.

The time that elapsed from the inception to the completion of the whole water supply scheme was from June, 1905, to October, 1910, an extraordinary long period apparently. This arose from a combination of causes, some of which may be briefly mentioned. The first and greatest was the inaccessibility of the site of the works. It was quite an undertaking to get even a pack horse to it when the locality was first decided upon; therefore, before the works could be started the whole of the roading, mountain side cutting and the two tunnels, had to be completed. This work occupied nearly two years. Then, again, the impounding dam could not be started till the clearing of the area was complete, on account of the enormous quantity of timber and *débris* that was carried down by every rise in the creek and past the site. This prevented the opening up of the trench through the bed of the stream, and also the building of intercepting timber dams and a flume.

The dam itself was started in August, 1907, and was only recently completed. This is undoubtedly slow work, but the city has received the water for the past two years, and storage was increased as the work rose.

Mr. James Carlaw, the City Council's permanent waterworks engineer, acted in conjunction with Mr. Munro Wilson in matters relating to general design. He also laid the 27in. main from the break pressure reservoir to Auckland; also the 20in. cast iron main from the dam to the break pressure reservoir.

The total outlay on the scheme, including engineering, cost of land, &c., was £150,000. The whole of the works were carried out under the supervision of Mr. Arnold Wilkins, inspector in charge, whose experience in waterworks construction, particularly relating to large concrete dams, was of a very extended nature, he having built five such dams while in the New South Wales Public Works Department. Three views of the dam are given in Figs. 2, 3, and 4.

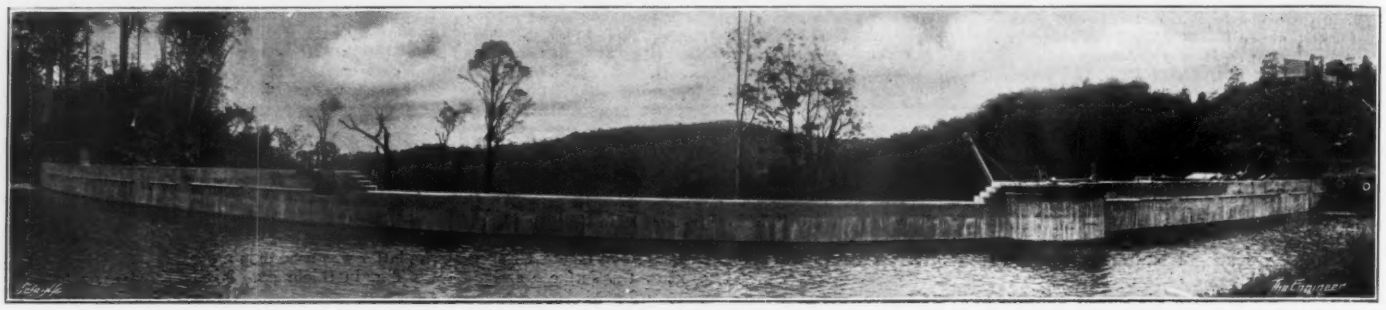


Fig. 3—UP-STREAM FACE OF DAM

Fig. 4—WAITAKEREI FALLS AND DAM

We are indebted to Mr. Munro Wilson for the major portion of the foregoing information.

THE Board of Trade have recently confirmed the undermentioned Order made by the Light Railway Commissioners:—Southend and Colchester Light Railways (Amendment) Order, 19 0, reviving the powers granted and extending the periods limited by the Southend and Colchester Light Railways Order, 1904, and by the Southend and Colchester Light Railways Act, 1905, for the compulsory purchase of lands for the purposes of part of the railway and works by that Order authorised, and of certain of the piers and works by that Act authorised, and extending the periods limited by such Order and Act respectively for the completion of such part of the railway piers and works, and authorising a deviation of part of the said railway and for other purposes.

ECONOMISER UTILITY.

THERE has been recently considerable discussion in German engineering circles of the commercial or economic value of that form of feed-water heater in which the feed is heated by the waste gases as they pass from the boiler flues to the chimney, which form is called an Economiser. Two of the latest papers on the subject lie before us, and they are of much technical interest. Space forbids a full translation of them, but we give an abstract of their main substance which will be sufficient for our readers.

The first paper is by Herr Kaufhold, the manager of a large factory. He remarks that the economic importance of utilising the waste heat sent up the chimney has been too long overlooked, and that the reason of this has been the want of a sound and simple method of calculating the possible saving. The heat in the waste gases depends upon their temperature, composition, and volume, the two latter depending again upon the coal burnt and the method of firing. The total heat of combustion of the fuel and the percentage of CO_2 in the gases are now quite commonly and accurately recorded in all important installations. The volume of the gases passing to the chimney per minute or per hour is difficult to measure directly with even rough approach to accuracy. It can, however, be found with a practically useful degree of correctness by chemical computation from the recorded CO_2 percentage. The heat of combustion of the fuel is taken as increasing in direct proportion to the carbon percentage, and Herr Kaufhold gives a straight line, or rather a two-straight line, diagram co-ordinating heat of combustion with carbon. For coals having over 50 per cent. C this diagram makes $H = 95\ C - 50$, where C is the percentage of carbon; and for inferior fuels which have little interest for English engineers, his diagram gives $H = 110\ C - 800$ in Centigrade heat units. Thus, at C = 50 per cent. the higher straight line gives $4750 - 50 = 4700$, and the lower line also gives $5500 - 800 = 4700$. Conversely from this diagram can be read off the percentage C corresponding to any experimentally measured H.

The heat in the flue gases increases with this heat of combustion, and therefore with C. Each kilogramme of fuel produces a nearly definite amount of CO_2 gas, and the total quantity of gas per kilogramme of fuel burnt is nearly proportional to $\frac{100}{c}$, where c is the recorded CO_2 percentage in the flue gases. The heat of combustion is distributed through this mass, and the heat given up by this mass of gas per 1 deg. fall in temperature is thus nearly in direct proportion to $\frac{C}{c}$. A correction has to be made for heat absorbed in the evaporation of moisture in the fuel and of water formed by the combustion of the hydrogen in the fuel. This term is small and nearly constant so far as it is useful to calculate for the purpose of estimating the commercial advantage derivable from the economiser. Minute accuracy is futile, because the result depends upon the moisture in the fuel, which varies with each truck-load delivered, and with the hydrogen and other combustible constituents, which also vary considerably. Herr Kaufhold now frames a diagram on which is drawn a series of nearly hyperbolic curves, each for one carbon percentage C. The ordinates are c, the CO_2 percentage, and the verticals are h, the heat obtainable from the mass of gas passing the flues per unit weight of fuel burnt per 1 deg. drop of temperature. In Centigrade units his formula is equivalent to $h = \cdot 6\frac{C}{c} + \cdot 24$. The last term ·24 really varies from about ·15 to ·30. A formula representing his curves more closely is $h = \cdot 2\left(\frac{3}{c} - 1\right) C + \cdot 37$. Knowing C and c, one can read h directly from the diagram; and if T and t are the temperatures at entrance to, and outlet from, the economiser $h\ (T - t)$ is the heat given up in passing it. The ratio of the heat actually put into the feed water to this last is the efficiency of the economiser. In his paper Herr Kaufhold gives various examples of the results of this simple calculation to the recorded tests of such apparatus, and to estimates of the money saving in coal obtainable by using an economiser. His diagram runs from $c = 6$ per cent. to $c = 16$ per cent., and from C = 20 per cent. up to C = 85 per cent.

The second paper referred to is one by Herr M. R. Schulz, who is a manufacturer of a form of economiser with wrought iron tubes, which has been in successful operation at many works for periods from one to six years. His thesis is that the ramification of the water-flow, and

also the reverse or contrary flow of water and flue gas, have a markedly good influence upon the thermal efficiency of any form of economiser. He begins by quoting the ordinarily used coefficient supposed to measure the good quality of such apparatuses. This coefficient equals the heat units received by the feed-water per unit area of the heating surface—internal, *i.e.*, washed by the water—per degree of difference between the mean gas temperature and the mean water temperature. Each of those

Herr Schulz quotes the published results of many trials of Green's and other forms of economiser of from 96 to 384 square metres heating surface, serving boilers evaporating from 2000 up to 6700 kilos. per hour under various conditions of temperature and of normal and of under and over load; and in each case he calculates K, and also the ratio of the drop of gas temperature to the rise of feed-water temperature. Both of these vary largely in the same installation. Values of K ranging from 7.8 to 16.8,

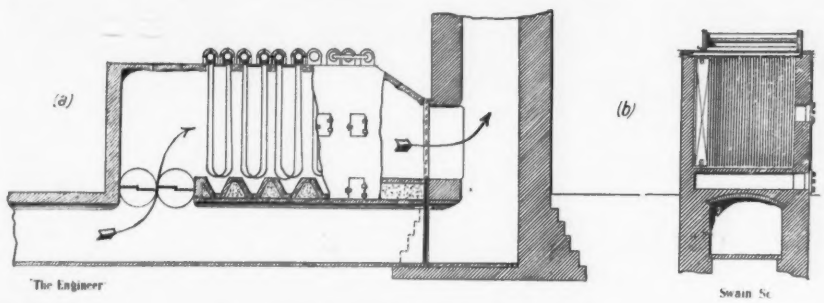


Fig. 1—SCHULZ ECONOMISER—VERTICAL TYPE

means is, in this formula, reckoned as half the sum of the entrance and exit temperatures. Herr Schulz states that this is not a complete gauge of the efficiency. This coefficient goes in Germany by the name Wärmedurchgangzahl, or otherwise Wärmeübertragungskoeffizient; but as there is not space in the columns of one issue of THE ENGINEER to repeat such names frequently, it will hereinafter be called simply K. To distinguish this from the more correct and complete measure of merit, we will call

and of the last-named ratio from 0.77 to 2.2 are found. Unfortunately, in many of these official trials the CO_2 percentage was not recorded, but other measurements show in what direction it must have varied; while both in these and when the CO_2 is measured the influence of this percentage is plain. Generally the above ratio is high when K is low.

Then the absolute temperature of the feed-water at entrance is markedly influential, low temperature greatly

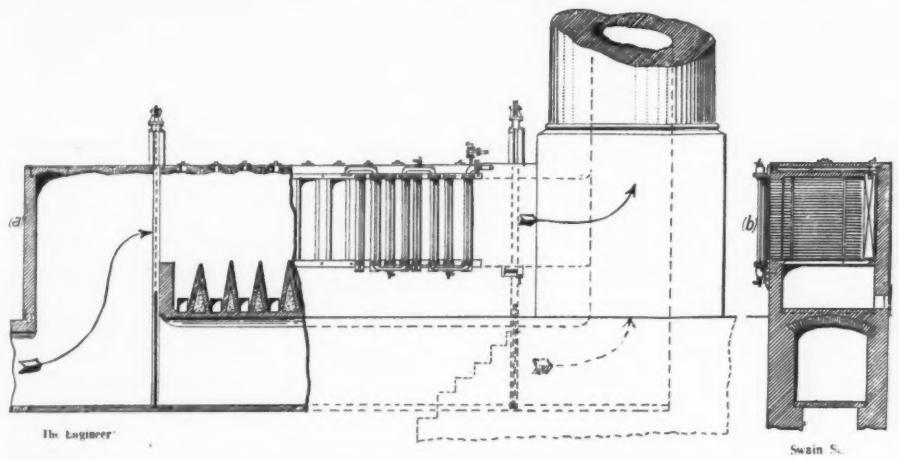


Fig. 2—SCHULZ ECONOMISER—HORIZONTAL TYPE

this latter E, which may stand for "Economy." Herr Schulz's main proposition is that E has a definite relation to the volume and the $C O_2$ percentage of the flue gases, the larger $C O_2$ percentage going with smaller volume and larger E. The coefficient K assumes that the utility depends only on the heating surface and the temperatures, whereas it is really affected in an important degree by the volume passing per minute. There has been much recent debate in England upon the effect of "high speed"

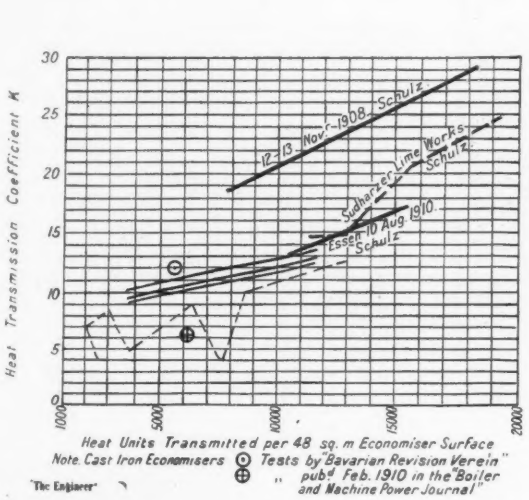
favouring the pseudo-efficiency K. Comparing two cases in which there was little difference in drop of gas temperature, but in which the inlet feed temperatures were 8 deg. and 120 deg. Cent., the former gave K = 15.5, while the latter gave only K = 7.8. In another comparison between forced and "natural" circulation of the feed-water through the economiser in the same installation, the former gave K 24 per cent. greater than the latter, while the weight of water heated was 20 per cent. greater. In

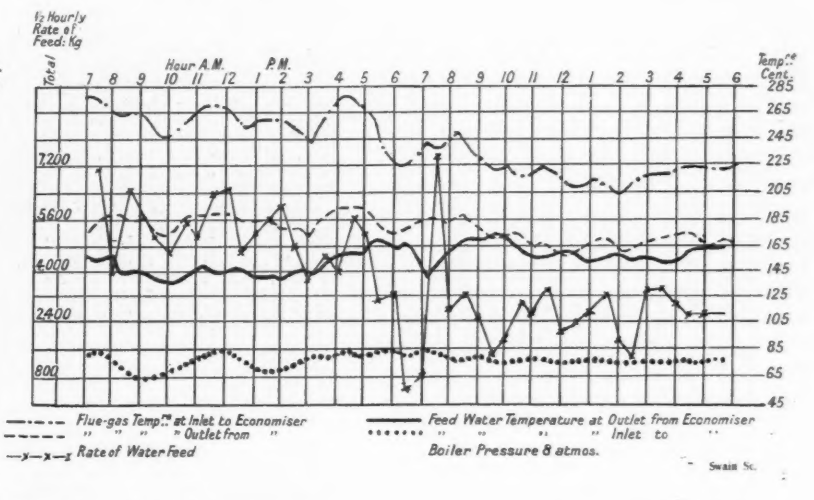
the larger quantity it is 1.4, or just ½, the same as the CO_2 ratio. In the first case the water temperature rose 52 deg. Cent., and the heat absorbed was 11,700 Cent. units; while in the second the temperature rose 74 deg., and 22,500 heat units, or nearly double the former amount, were absorbed.

Herr Schulz then critically examines a series of twenty-one official tests of cast iron economisers of about the same size, but of three different forms, one of them with contrary circulation of flue gas and water. In each of the seven tests of each plant the feed-water passed was diminished over a range in the ratio of about 2 to 1; the inlet water temperature was only slightly raised as the load decreased; and the inlet gas temperature was decreased slightly. There was very little change throughout in the CO_2 percentage, which was low, namely, a little over 6. The heat taken up by the water decreased in the ratio 3 to 1 with parallel circulation, and in the ratio 2½ to 1 with contrary circulation; while the K diminished in the approximate ratio 4 to 3 in the first case, and about 5 to 4 in the second. It is thus evident that K varies largely in each economiser with the conditions of working; but this series does not exhibit its variation with CO_2, since this remained nearly constant throughout. In this series K varies from 13½ down to 9. The heat units absorbed per hour per square metre of economiser surface varies from 2560 down to 760, and Herr Schulz deduces that not more than 2400 can be taken economically. He points out that if an economiser manufacturer puts in extra large surface in order to ensure fulfilling his guarantee he is bound to reduce the K of his apparatus, since this is reckoned per square metre. The contrary circulation gave in this series of tests a K about 9 per cent. better than the mean of the two parallel circulations. His examination of these and other tests of cast iron economisers leads Herr Schulz to conclude that their K is about 12½ with 6 per cent. CO_2, about 10 with 8 per cent., about 8 with 10 per cent., and 6 with 12 per cent. CO_2.

He then proceeds to detail several series of tests of his own wrought iron tube economisers undertaken by three independent boiler associations. The surfaces of these varied from 100 to 580 square metres, and the feed water passed per hour from 4500 to 28,750 kilos. The inlet water temperature varied from 35½ deg. to 78½ deg. Cent., and the gas entrance temperature from 224 deg. to 320 deg. Cent. The CO_2 was varied purposely, and ranged from 3.8 up to 9.6 per cent. The boiler evaporation per hour per square metre boiler heating surface varied from 10¼ to 29½ kilos., corresponding to from 2½ lb. to 6 lb. per square foot. The values of K obtained range from 12½ to 24, and the heat taken up per hour per square metre of economiser surface ranges from 1500 to 4000. The first series of tests shows very distinctly that the heat absorbed per unit economiser surface increases with the evaporation per unit boiler surface, and this without any great rise in flue-gas entrance temperature. This rose only from 224 deg. to 312 deg. Cent., while the evaporation rose threefold, and the heat taken by the economiser rose two-fold, the CO_2 per cent. also rising from 3.8 to 9.3.

The series in which the very high figure 4000 was reached shows this result also equally plainly. In it, doubling the boiler evaporation raised the economiser heating power by 54 per cent. This heating power 4000 corresponded to the value K = 24.1. Herr Schulz points out that with forced draught the economiser efficiency may be raised still higher. One of the economic limits imposed upon it is the necessity of sending to the chimney sufficient heat to create the natural draught required, and to force the boiler to a high overload activity with natural draught greater quantities of heat must be sent up the chimney. The 4000 figure was attained with entrance water temperature 68 deg. Cent. = 154 deg Fah., and entrance gas temperature 321 deg. Cent. = 610 deg. Fah., that is, with quite hot feed water and only very moderate flue-gas temperature. These results are obtained by





Figs. 3 and 4—TESTS OF SCHULZ ECONOMISERS

on the efficiency of boilers; but the mistake has been made of attributing to high *linear* velocities the effects really due to the passing of larger masses of hot gas per minute. The difference is very important, because these masses increase with the quantity of coal burnt, and therefore with the chief running cost of the installation; while if regard is paid exclusively to extent of heating surface, this indicates only a relation to prime cost of construction.

the former case the feed-water absorbed 37 per cent. more heat than in the latter.

Again, in official tests of two Green's economisers of the same heating surface, 96 square metres, and passing per hour 2247 and 3042 kilos. of feed-water, the two K's were 7.2 and 14.4, and the two CO_2 percentages 12.7 and 6.0. The K ratio is 2 and the CO_2 ratio about ½. With the smaller quantity of water passed the ratio between fall of gas temperature to rise of water temperature is 2.9; with

sending the water through parallel groups of small wrought iron tubes, the groups being arranged in series. The water is led forwards and backwards in a designedly tortuous path through a series of gas-temperature zones. Through these the flue gases pass, so that the hottest gas comes in contact with the hottest water. The number of tubes in each group and the number of groups placed in series is designed according to the duty demanded and the working conditions of the boiler, of which the CO_2 per-

centage is deemed the most important. All the joints are flanged and bolted, and are all outside the brickwork. It is claimed that there is no sweating and no adhesion of dust and ashes to the tubes, so that without any scraping these keep clean, the dust falling to the corrugated floor, from which it is easily swept out through small cleaning doors; also that lime deposit inside the tubes is removable by a special process, which can be carried out without throwing the plant out of operation.

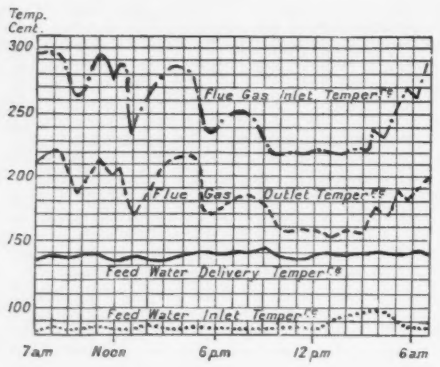


Fig. 5

Fig. 1 (*a*) and (*b*) give longitudinal and transverse vertical sections of the type of this plant, with the tubes placed vertically, and Fig. 2 shows the same when the the tubes are arranged horizontally. Fig. 3 is a diagram comparing its test results with those of various cast iron economisers.

Fig. 4 is a diagram of one of the most interesting tests of the Schulz economiser with eight atmospheres boiler pressure and a chimney of 75 m. height, giving a draught of 36—30 mm. W.G. It will be noted that the rate of feed was extremely variable; and that when it was low

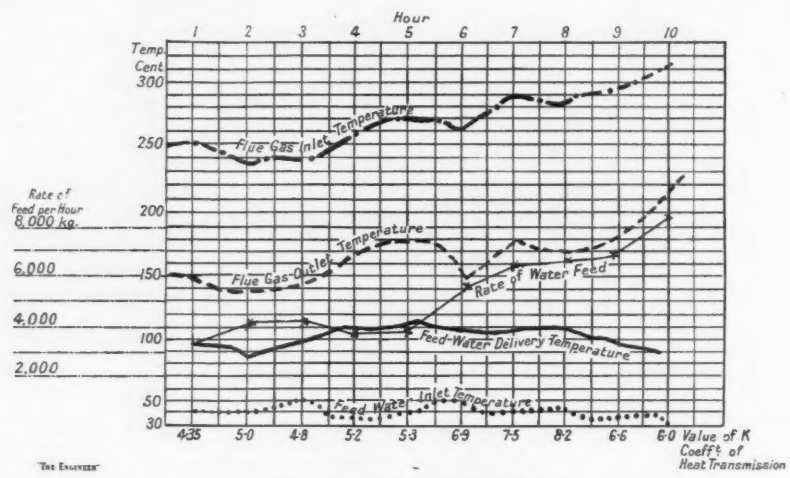


Fig. 6—TEST OF CAST IRON ECONOMISER

the final temperatures of flue gas and water approach each other closely, while when the feed was rapid these two curves keep well apart, the gas being less cooled and the water less heated. Between 8 and 9 in the morning the value of K works out to 29.2; but the great unsteadiness brings the mean over 12½ hours down to 22. In this case the CO_2 percentage ranged from 4 to 6, showing very unskilful firing.

Fig. 5 is also specially interesting. Here the chimney is 60 m. high and gives a draught of 25—20 mm. W.G. The CO_2 percentage varied from 12 to 14, and the feed

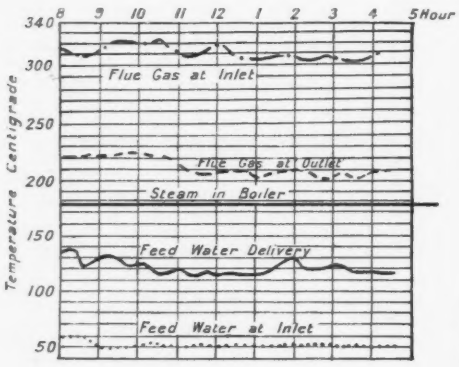


Fig. 7

and general working were steady. The feed temperature at inlet is uniform except for a rise of 30 deg. between two and five o'clock in the morning; and its temperature at delivery is nearly uniform. The flue gas temperature varies according to the firing, and the remarkable point to note is that the drop of gas temperature in passing through the economiser is almost exactly uniform throughout in spite of large and somewhat sudden changes in inlet temperature. The smaller draught and the consequent smaller quantity of gas passing makes the value of K less than in Fig. 4; it ranges from 14 to 24. These two diagrams are from plants differing only slightly in size of both boiler and economiser, the boiler heating surfaces being 512 and 504 square metres, and the economiser heating surfaces being 291 and 300 square metres; but in Fig. 5 the boiler was evaporating only little more than half its normal capacity, namely, from 9 to 12 cubic metres water per hour.

Fig. 6 is a case of a cast iron economiser showing gradual rise of the load on the boiler, the rate of feed and the gas temperatures at inlet and outlet all rising together. The delivery feed-water temperature at first rises, then keeps fairly steady until 8 p.m., when it begins to fall on account of excessive overload. The varying values of K are marked along the base of the diagram.

Fig. 7 is another example of running under more steady conditions. Here the average K is 17¾.

Herr Schulz's main proposition is that comparatively small-sized wrought iron tubes, with well-divided water circulation, leading each portion of water systematically through zones of gradually increasing gas temperature, give the highest economiser efficiency; that by special construction the well-known difficulties in the use of small tubes with limy water can be overcome so as to leave the tubes unaffected for many years; and that the amount of heat absorbed per hour and per square foot of surface depends greatly upon the quantity of gas passing per pound of fuel burnt and of steam generated, and that this can be calculated with fair practical accuracy from records of the CO_2 percentage.

TWO NEW DREDGERS.

THE Hai-Ho which connects Tientsin with the sea is a river with numberless shallows formed by sand and mud, and was at first difficult to negotiate by large steamers on account of the many curves. Since the Boxer rising in 1900, continuous efforts have been made to improve this important means of communication, and with no small measure of success. A commission, consisting of a nominee of the Chinese Government, the Chief of the Customs at Tientsin, one of the foreign consuls, and a representative of the foreign traders at Tientsin, are giving assiduous attention to the Hai-Ho River. In order to do away with some of the curves, three cuttings have been made, and a fourth has been resolved upon. The Taku bar, which renders the mouth of the river difficult of navigation, will also be taken in hand. For these fresh works, which have just started, new dredging plant had to be ordered last year, and A. F. Smulders, Schiedam, Holland, were commissioned to build a twin-screw combined suction and bucket dredger. This vessel was completed at the firm's yards in the beginning of April last, and made the voyage to the Far East under her own steam. The Hsin-Ho, as the dredger is called, is able to cut her own floatation, and to discharge the spoil into barges alongside or through a floating pipe line of a diameter of 20in., and a length of 1000ft., to a height of 9ft. above water level, when dredging either by the suction apparatus or by the bucket chain.

The main dimensions of the vessel are:—Length between perpendiculars, 157ft. 6in.; breadth, 36ft. 9in.; depth, 11ft. 6in. The dredging depth of the Hsin-Ho, when dredging by suction or by the bucket chain, with the ladder at 45 deg., is 26ft. Her theoretical output is 500 cubic metres per hour. With 25 tons of coal in her bunkers, 10 tons of water in the tanks, water in the boilers; condensers, piping and outfit in working order, the vessel's maximum draught is 6ft. 6in. The mean speed when normally equipped is 8 knots.

The main engines are two in number. They are of the inverted type, compound, steam jacketed, with surface condensers. They are designed to develop 320 indicated horse-power each at about 140 revolutions a minute. When the engine runs at 140 revolutions, the bucket chain attains a speed of 14 buckets a minute. The capacity of the buckets is 600 litres each. The two main boilers are of the multitubular return tube type, and have a heating surface of 1380 square feet, and a working pressure of 120 lb. each. Besides the sand pump and the usual winches, the dredger has a high-pressure centrifugal pump for working the nozzle stirring arrangement fitted at the mouth of the suction pipe. Messrs. Smulders also provided a floating pipe line of a length of 1000ft. to be used with this dredger.

Another dredger which has left the Werf Gusto during the past few months is the Adelaide, a bow-well bucket dredger, destined for Adelaide harbour. This vessel likewise made the voyage to her destination under her own steam. The principal dimensions of the Adelaide are:—Length, 161ft.; breadth, 34ft. 6in.; depth, 13ft.; dredging depth, 43ft. The hull has been built of mild steel to Lloyd's rules, Class 100 A, and under special survey. On board the dredger are a compound engine of 500 indicated horse-power, an auxiliary compound engine of 150 indicated horse-power, a self-contained surface condensing plant, driven by its own engine, and a special centrifugal pump to supply water for mixing with the spoil in the shoots. The boilers, two in number, are of the marine type, with a heating surface of 1930 square feet, and a working pressure of 120 lb. At the official trials the output obtained was, we are informed, 630 cubic yards per hour, this being 130 cubic yards in excess of the quantity contracted for, and the speed was upwards of 7 knots.

Views of both these vessels are given on page 696.

LOCK-AND-BLOCK.

RECENT railway accidents have revived the interest in the union of the block instruments with the levers working the outdoor signals, a method that is generally known as "lock-and-block." This may be briefly explained as a system whereby a signal controlling the entrance of a train into the section in advance cannot be lowered unless permission has been given on the block instrument by the man at the advance box, which permission cannot be given until the instrument has been "cleared" for the previous train, and, in turn, this train-out-of-section block signal cannot be sent until the previous train has passed over an electrical contact maker. This contact causes a lock to be taken out of the handle of the block instrument, and allows it to be placed in the normal position, and so "clear" the section.

The system is also applied so as to govern the movements of trains and engines out of loops, sidings, and through cross-over roads on to the main line, and it is so installed, as well as being applicable to straight running, on the London and South-Western, Great Eastern, South Eastern and Chatham, and other railways. It will therefore be seen that there is apparently a method whereby the errors made by the signalmen at Ormskirk, Willesden, and Hawes Junction might be avoided.

For suburban lines the system works very well, but trouble comes in when there is shunting to be dealt with. This is due to the necessity for providing a contact maker to guard against the train-out-of-section block signal being prematurely given, and this contact has to be placed some distance in advance of the starting signal. If, then, a goods train arrives at a station, and it is shunted into a siding, the contact maker will not be depressed and a releasing apparatus has to be provided. While the improper use of the release is safeguarded as much as possible it still remains a weak point.

Where there is a movement from a siding, say from the engine shed at Ormskirk, the pulling over of the lever of the siding points locks the block instrument automatically and the light engine is thus protected against a train being accepted. But if this arrangement were employed, say at Hawes Junction, where seven engines are moving to and fro, there would be such a continual locking and unlocking of the block instruments that the system would develop into a nuisance, and the remedy become as bad as, if not worse than, the disease.

Fortunately, there is available a method that has none of these objections, and that is track-circuiting. By this the rails of the main lines are bonded together and a relay at the entering end of a section is joined up through the rails and bonds to a battery at the outgoing end. The relay controls the lever working the entering signal, and may also control other levers that may require locking. The presence of a wheel on the section short-circuits the battery, so that the relay drops and the lever becomes locked.

Track-circuiting was at one time regarded with suspicion by British railway men, but their prejudices have been overcome, and now some lengths of line so equipped are to be found on most railways. In Mr. Rayner Wilson's "Power Railway Signalling" these systems of "lock-and-block" are fully described, and we there learn that there are two objections to track-circuiting—that light wagons will not always "shunt" the current, and that wheels with wooden discs do not give a complete circuit. The former objection is a minor one, and may be neglected, and as to the other it is interesting to know that the advance of track-circuiting has led to those companies who do not use solid wheels bonding the boss and tire together. There still remains the important question of cost. If the whole length of the sections is to be treated, the expense will be very great, but had only the lines within the protection of the home signals, *i.e.*, in the station or yard, been so fitted at Ormskirk, Willesden and Hawes Junction, the recent accidents there would not have occurred.

CRYSTAL PALACE ENGINEERING SCHOOL.—The "Wilson Premium," for the best paper read before the Crystal Palace Engineering Society during the present session, has been awarded by the Council to E. Bayly, for his paper on "Steam as Applied to Motor Cars." Other papers read during the session were:—"Lighthouses," by C. A. Brown; "Wireless Telegraphy," by E. C. Coke; and "Street Lighting," by M. M. Thurley. Mr. H. A. Minchin, chief engineer, P.W.D., Travancore (old student), also gave an interesting address on "Irrigation in India." The premium was presented to Mr. Bayly by Mr. Alexander Siemens, president of the Institution of Civil Engineers, on the occasion of the 114th award of certificates of the above school on Wednesday, December 21st, at which he presided.

INSTITUTE OF MARINE ENGINEERS.—At the Institute of Marine Engineers on Monday, December 12th, a lecture to the Junior Section was given by Mr. J. G. Hawthorn (member of Council) on "The Steam Engine Indicator." Mr. William McLaren (member) occupied the chair. The lecturer, in the first place, described the indicator diagram as a graphical representation of the work done during one stroke of the engine. By taking the difference between the forward and back pressure of the piston at any particular moment the effective pressure at that moment could be ascertained, and the mean effective pressure by taking the average of a number of such measurements from the indicator card. From this the lecturer demonstrated how the horse-power could be worked out. He then described how to read the indicator diagram and the inferences to be drawn from it. He then considered the question of pressures and how to measure the pressures from the diagram to see how it corresponded with the steam gauges, afterwards considering the effects of faults in the distribution of the steam, the result of advancing or putting back the excentric, &c., the cards likely to be produced by linking up the remaining cylinders of a triple-expansion engine in the event of one failing, and the results of leaky cylinders, concluding with a description of one or two repairs.

THE CAPITAL SHIPS OF ENGLAND AND GERMANY.

THE table below is given to emphasise and corroborate the facts published in our leading article of to-day regarding the output of heavy armaments in England and Germany. Exact information as to the armament of the 1910 German vessels is still lacking, but we quote from German sources tempered with knowledge of the earlier designs of these vessels. The greater homogeneity of the British divisions becomes apparent on inspection. We possess eight practically similar battleships and four cruisers of the 1905 to 1908 programme, that is, practically two types only, as against the corresponding German five types. The amazing development in large German ordnance is, perhaps, best illustrated by comparing the many admirals say four to two. An equality is not sufficient to ensure the inviolability of the coast line which must in the present state of army organisation be a *sine qua non*. Just one hundred years ago someone questioned the ability of the then First Lord of the Admiralty to prevent invasion by Napoleon. "I don't say the French cannot come," replied Lord St. Vincent, "all I say is they cannot come by sea." That is the position that should be absolutely demanded of any Board of Admiralty in power; the cost of an unsuccessful continental war will be double or treble, maybe five times that of another fleet, as big as the existing one. Whatever the cost involved may be, it is no less impossible now than it was in St. Vincent's time to forfeit the commanding position both in peace and war expressed by the trite phrase "they cannot come by sea."

Comparative Statement of Capital Ships Ordered by Great Britain and Germany since the Commencement of H.M.S. Dreadnought.

GREAT BRITAIN.

Date.	Battleships and large cruisers ordered.	Number of twin turret mountings.	Number and size of guns.	Weight of guns, individual and total, tons.
April, 1905—March, 1906	Dreadnought, Invincible, Indomitable, Inflexible	5, 4, 4, 4 = 17	34 12in., 45 cal.	58 1972
April, 1906—March, 1907	Bellerophon, Temeraire, Superb	5, 5, 5 = 15	30 12in., 45 cal.	58 1740
April, 1907—March, 1908	St. Vincent, Collingwood, Vanguard	5, 5, 5 = 15	30 12in., 50 cal.	66 1980
April, 1908—March, 1909	Neptune, Indefatigable	5, 4 = 9	18 12in., 50 cal.	63 1188
April, 1909—March, 1910	Colossus, Hercules	5, 5 = 10	36 12in., 50 cal.	66 2376
	Orion, Lion	5, 4 = 9	18 13·5in., 45 cal.	81 1458
	*Australia, *New Zealand	4, 4 = 8		
April, 1910—March, 1911	*Monarch, *Thunderer, *Conqueror, *Princess Royal	5, 5, 5, 4 = 19	38 13·5in., 45 cal.	81 5346
	*3 others	5, 5, 4 = 14†	28 13·5in., 45 cal.	
Totals	Battleships, 16 Large cruisers, 9	74 12in. mountings 42 13·5in. mountings	148 12in. guns 84 13·5in. guns	
In six years	Capital ships, 25	116 twin mountings	232 guns	16,060 tons

GERMANY.

April, 1905—March, 1906	Schlesien, Schleswig-Holstein	2, 2 = 4	8 11in., 40 cal.	31 248
April, 1906—March, 1907	Nassau, Westfalen	6, 6 = 12	24 11in., 45 cal.	36 864
April, 1907—March, 1908	Rheinland, Posen, Von der Tann	6, 6, 4 = 16	32 11in., 45 cal.	36 1152
April, 1908—March, 1909	Helgoland, Thuringen, Ostfriesland, Moltke	6, 6, 6, 5 = 23	46 12in., 50 cal.	52 2392
April, 1909—March, 1910	Oldenburg, *Ersatz Hildebrand, *Ersatz Heimdall, "H"	6, 6, 6, 5 = 23	46 12in., 50 cal.	52 2392
April, 1910—March, 1911	*Ersatz Odin, *Ersatz Hagen, *Ersatz Aegir, *"J"	5, 5, 5, 5 = 20†	40 14in., 45 cal.	70 2800
Totals	Battleships, 15 Large cruisers, 4	32 11in. mountings 46 12in. mountings 20 14in. mountings	64 11in. guns 92 12in. guns 40 14in. guns	
In six years	Capital ships, 19	98 twin mountings	196 guns	9848

* Signifies not yet launched.
† Exact details of these armaments uncertain, but these figures are believed to be practically correct.

table of total weight of finished guns ordered per year, which is, in 1910, no less than 11.3 times that ordered in 1905, compared with the English ratio of 2.66 to 1. This increase represents a tremendous addition to steel furnace capacity, and could only have been permitted in the face of fairly certain knowledge that the demand would continue. Where the British Government seems to have lost ground is shown in the 1908-9 estimates compared with those of Germany. The last line indicates the relative status as accurately as has yet been put forward. We had ordered up to the end of November only sixteen battleships (one more has been ordered since) to the fifteen of Germany, and nine cruisers to her four, though two of ours, of course, are being bought and paid for by colonial patriotism. It shows as clearly as can be put on paper that a margin of superiority is existent, but, whatever may be said to the contrary, it is virtually nil. It is on record that, on his stating that there was no fruit in a certain orchard, Dr. Johnson was contradicted by some captious critic who had discovered two pears and one apple. "I said Sir, there is no fruit in that orchard," was the reply. So it is with the word margin. For a fleet that has to operate on an enemy's coast the margin of superiority over the opposing fleet needs to be at least three to two;

OBITUARY.

JAMES MELDRUM.

WE regret to have to announce the death on the 15th inst. at Colombe Lodge, Ealing, of Mr. James Meldrum. Mr. Meldrum was born in Fifeshire in 1855, and was educated at the Madras College, St. Andrews, passing on to the University there and afterwards to that of Glasgow, in all of which he carried off first-class honours.

He received his engineering training in the office of Messrs. Bell and Millar, Glasgow, MM. Inst. C.E., and was engaged thereafter on important railway works for Ward and Co., of Carlisle and Glasgow. In 1881 he went to Brazil and became chief engineer for the construction of the Conde d'Eu Railway, the first in the Province of Parahyba.

Among the many important works he was engaged in was the construction of the Manila Railway, the first in the Philippine Islands, the Buenos Ayres Great Southern Railway, of which, as chief constructional engineer, he carried out large extensions. For twelve years he was manager of the foreign department of S. Pearson and Son, Limited, for whom he directed extensive works in China, Colombia, Chile and in Mexico, including the reconstruction of the Tehuantepec Railway, with the terminal harbour and docks on the Gulf of Mexico and on the Pacific, all of which work was carried out to his designs.

During the last few years, as consulting engineer, he gave expert advice on an immense amount of work, and was also on the board of several companies. He was a man of exceptional ability and an attractive personality. He was a member of the Institution of Civil Engineers.

THE INSTITUTION OF CIVIL ENGINEERS.

THE WINNING OF COASTAL LANDS IN HOLLAND.

AT the ordinary meeting on Tuesday, the 20th December, Mr. Alexander Siemens, President, in the chair, the paper read was "The Winning of Coastal Lands in Holland," by A. E. Carey, M. Inst. C.E. The following is an abstract of the paper:—

The first section deals with the history of the gradual reclamation of the Dutch lowlands from the sea, and the general topography of the country. Reference is then made to historic inundations, and to the devastation which the country has suffered from time to time by the bursting of the protective dams, and the principal reclamations, which have so largely altered the map of Holland, are referred to, particularly that of the Lake of Haarlem, the first reclamation of which was carried out between the years 1540 and 1648. The so-called lake consisted of a vast swamp. The final works of reclamation were carried out by the State in 1840. The author advances the theory that several of the breaches in the sand dunes on the North Sea coast represent former embouchures of the river Rhine.

The gradual accretion of alluvium on the tide-washed mud and sand flats is then described, as well as the means by which one piece of the foreshore after another is gradually won from the sea, reference being made to the means by which the drainage is effected. The administration of the Dutch sea defences is next dealt with, and comparison is drawn between the Polder Boards of Holland and the Courts of Level Commissioners in England. The standard levels in Holland are then referred to, the author pointing out that the level of Amsterdam Peil, worked to by the Dutch engineers, differed only by about 1ft. from the level of the Ordnance Datum. Reference is made to the employment of accumulation reservoirs, and the functions which the sand dunes and navigation canals play in this respect.

The geological formation of the Netherlands is next discussed, and the various levels of the different strata are given. The gradual weakening of the natural protection afforded by the sand dunes is referred to, and some interesting evidence is brought forward to show how great the alterations in the position and magnitude of the dunes have been. The methods by which changes in location of the sand dunes are arrested, such as the planting of grasses on the faces of the dunes, and the protection of them on the land side by the planting of various kinds of trees, are dealt with, and a sieve analysis of dune sand is given. Reference is made to the action of wind and sea on the dunes, and attention is called to the difference in the angles of repose of their sea slopes and land slopes.

The construction of the typical Dutch "dike" or "dam" is then discussed, and a method of thatching earth slopes with straw is described, some details of the cost of facing the larger dams being given. A comparison is drawn between the principles adopted by engineers in Holland, and those of such river-walls as protect the Essex marshes in England. The gradient of the sea face of these walls is steeper than in the Dutch walls, which necessitates a higher crest-level in the latter case. The author describes a singular phenomenon, known as a "fall," which occurs on the submarine slopes, forming the toe of a protective dam, and discusses its causes. Attention is called to the extreme depths of water which occur close in to the artificial coast-line. The steps taken by Dutch engineers to repair the sites where "falls" have occurred are explained. Reference is then made to the facing of sandy foreshores with concrete, and a short explanation of the new systems of coast defence work, adopted by Mr. de Muralt.

The paper then gives a brief account of the principal works of reclamation in Holland, including, amongst others, the West Kapelle dam, Osse breakwater, the Langendijk, the Hondsbosse dam, the Petten dam, and the Prinz Hendrik dam, at Texel. The greatest project of all, however, is that for the reclamation of the Zuyder Zee, and the author describes briefly financial and economic considerations pertaining thereto, and the schemes put forward by Van Diggeen in 1849, and Colonel Biejerinck in 1865, and the findings of the Dutch Royal Commission of 1892.

BOOKS RECEIVED.

The City Diary, 1911. London: W. H. and S. Collingridge, *City Press* Office, 148 and 149, Aldersgate-street, E.C. Price 1s.

Standard Specifications. By J. C. Ostrup. London: Hill Publishing Company, Limited, 6, Bouverie-street, E.C. Price 4s. 6d. net.

Electric Motors. By Francis B. Crocker and Marton Arendt. London: Crosby Lockwood and Son, 7, Stationers' Hall-court, E.C. Price 10s. 6d. net.

The "Practical Engineer" Pocket-book for 1911. London: The Technical Publishing Company, Limited, 55 and 56, Chancery-lane, W.C. Price, cloth, 1s. net; leather, 1s. 6d. net.

The South Wales Coal Annual, 1911. Edited by J. Davies and C. P. Hailey. Cardiff: The Business Statistics Publishing Company, Limited, 12, James-street. Price 7s. 6d. net.

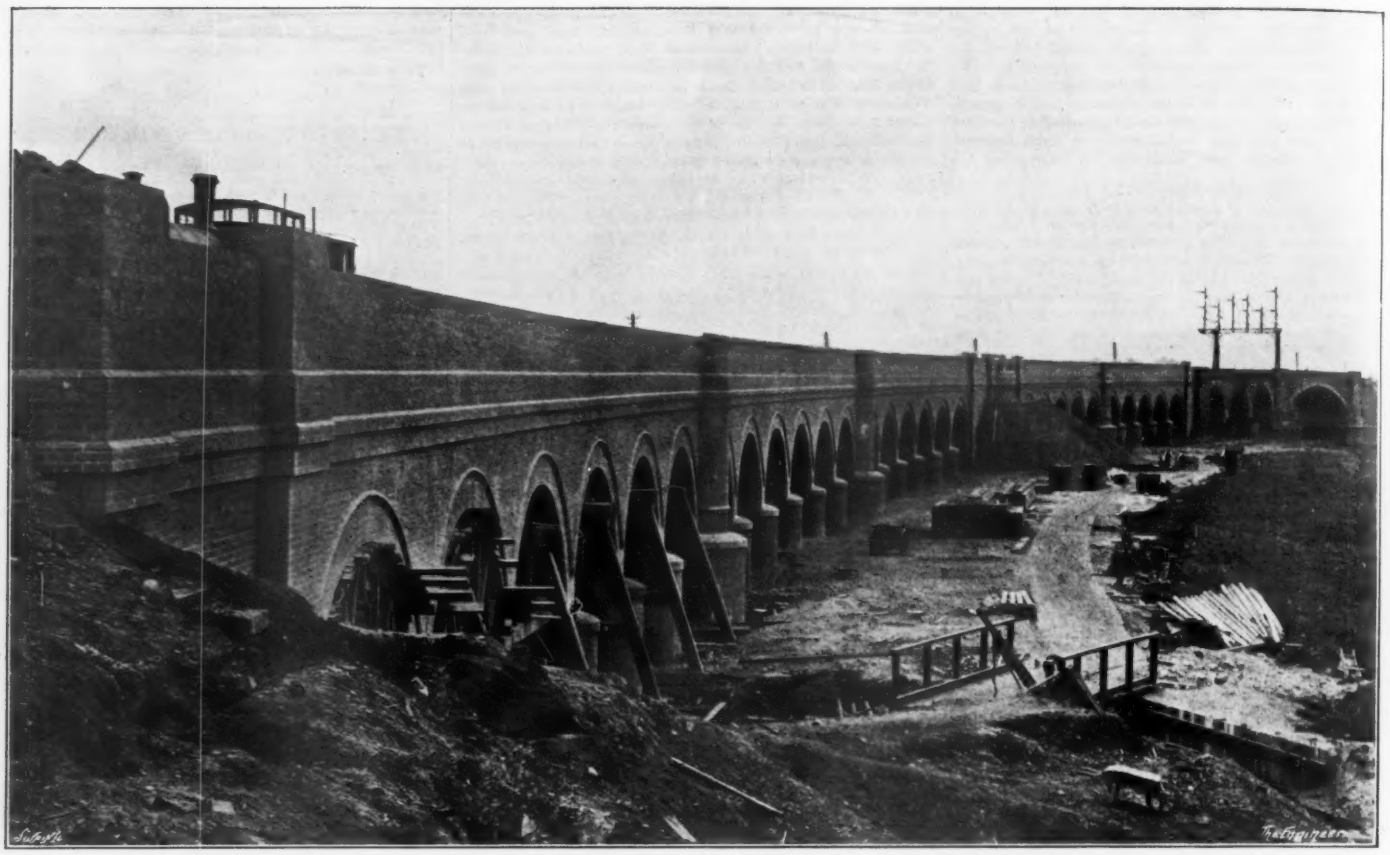
The "Practical Engineer" Electrical Pocket-book and Diary, 1911. London: Technical Publishing Company, Limited, 55 and 56, Chancery-lane, W.C. Prices, cloth, 1s. net; leather, 1s. 6d. net.

The Technical Dictionary in Six Languages. By Alfred Schlomann. Vol. IX.: *Machine Tools for Metal Working and Wood Working*. London: A. Constable and Co., Limited, 10, Orange-street, Leicester-square, W.C. Price 9s. net.

ACCORDING to the annual report of the London County Council for the year ended 31st March, about 30 miles of new tramways were opened during the year, at the close of which the length of the tramways in use was 136 route miles. The average daily number of cars running is 953 electric and 120 horse. During the year 451,439,216 passengers were carried, there being over 210,000,000 passengers at penny fares, while 43,160,186 car miles were run. The total capital expenditure on the undertaking up to 31st March amounted to £10,709,504, of which £1,225,942 represent expenditure during 1909-10. The total receipts amounted to over £2,023,000, and the working expenses totalled £1,234,000.

THE RECONSTRUCTED RADCLIFFE VIADUCT

MR. ALEXANDER ROSS M. INST. C.E., KING'S CROSS, ENGINEER

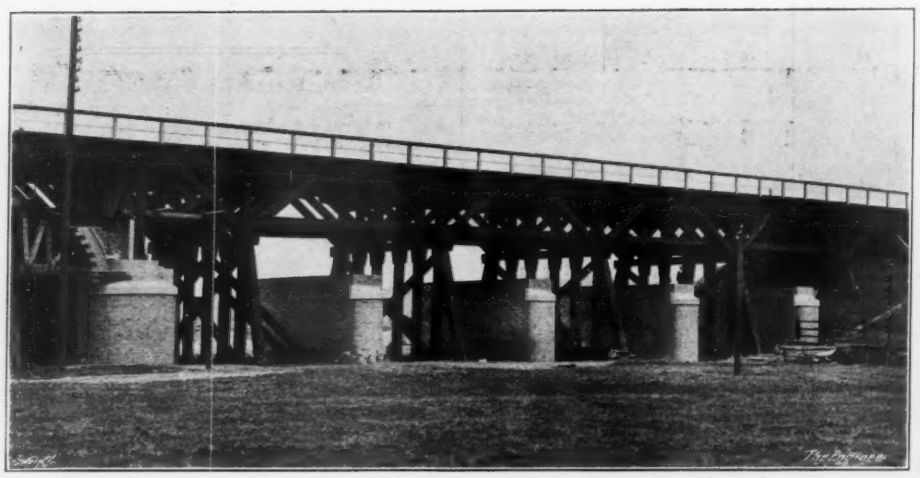


THE RECONSTRUCTION OF THE RADCLIFFE VIADUCT.

DURING the past two years the Radcliffe Viaduct, on the Great Northern Railway, which was originally built in timber, has been entirely reconstructed in brickwork. The Nottingham and Grantham branch of the line, on which it is situated, formed a portion of a separate undertaking known as "The Ambergate, Nottingham, and Boston and Eastern Junction Railway," originally intended to run from Ambergate, in Derbyshire, to Boston, in Lincolnshire. The portion between Grantham and Nottingham, however, was the only part constructed, and this was taken over by the Great Northern Railway Company in 1862. A bridge was erected over the river Trent, consisting of three brick arches of 32ft. 6in. span and one cast iron arch of 107ft. span. In the course of the construction of the line it was found that there was a deficiency of earthwork from the cuttings to form the banks, and therefore it was determined to build a timber viaduct from the above bridge to the Wharf-road at Radcliffe, a distance of 45 chains. A portion of this was subsequently filled up with earthwork, it being apparently intended to treat the whole length in this way, leaving only flood openings; but on account of local opposition, this scheme was never completed, and the timber viaduct which has been recently replaced was left standing with a bank in the centre, which has had to be retained in the new structure in consequence of an agreement then come to.

The original engineer for the line was Mr. John U. Rastrick, of London, the resident engineer being Mr. John Underwood, who, in 1850, became chief engineer, and afterwards new works engineer to the Midland Railway Company. The contractors were Greaves, Smart, and Adams, who commenced work on the viaduct on the 5th February, 1848, and it was finished in June, 1850, and the line opened for traffic on the 15th July of the same year. The timber structure, therefore, stood for nearly sixty years.

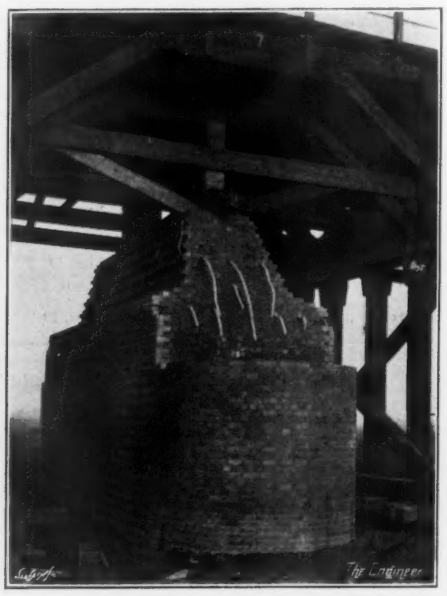
The first brick of the new viaduct was laid on January 19th, 1909, and the last portion opened for traffic on September 5th, 1910. The work was stopped for several weeks last winter by floods. The following is a description of the new viaduct and the method of erection:—The total length of the viaduct, including the bridge over the river Trent, is 19 chains. The new portion consists of 28 spans, eighteen of 24ft. 11in. and ten of 25ft. 7in. each, with a double abutment between them on the bank described above. The arches are divided into five sets, and are separated by stop piers 10ft. in width, the intermediate piers being 4ft. 1½in. The arches are five rings in thickness, and are covered with blue brick paving. Cutwaters in brickwork have been formed at each end of the piers, as the floods from the river run in both directions from the bridge. Manholes have been formed on the stop piers, and large circular recesses on the central bank to form places for look-out men in times of flood.



THE OLD VIADUCT, SHOWING THE CONSTRUCTION OF THE NEW PIERS

The foundations of the piers average 10ft. in depth, going through a bed of gravel on to a bed of marl, which forms part of the Keuper formation. The concrete in the foundations was made with six parts of broken slag, and gravel obtained during the progress of the work, and one of cement. The concrete was made of this strength as considerable difficulty was experienced at times with water in the foundations, which at the normal level of the river rose through the gravel to within an average of 6ft. from the surface of the ground. The viaduct was built of local bricks faced with Staffordshire brindled bricks, the whole of the work being done in cement with mortar composed of one part of cement to three of sand. The stone in the caps of the cutwaters and coping is Derbyshire.

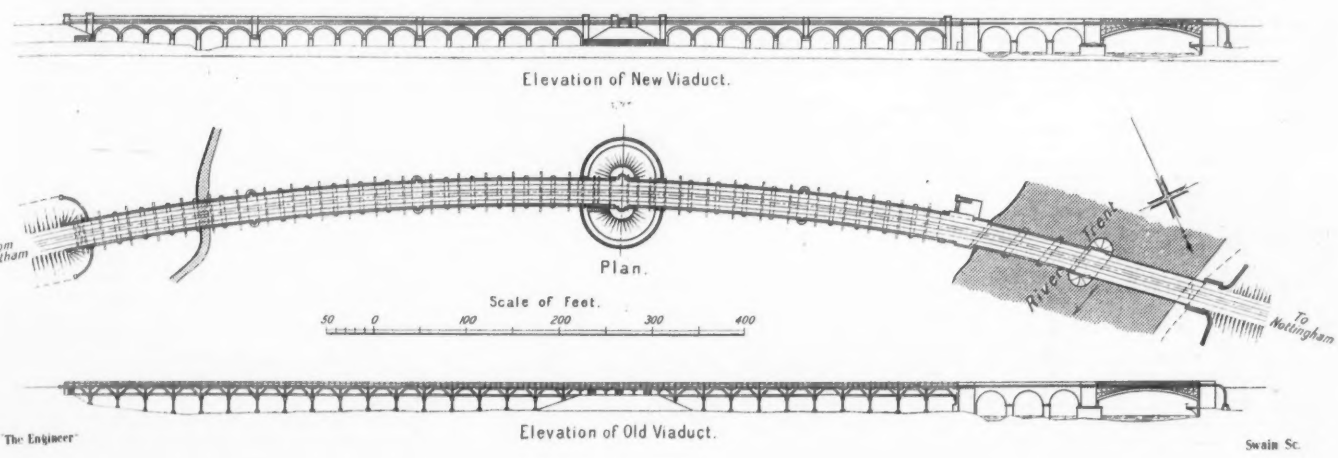
The following is a brief description of the method adopted in the carrying out of the work:—In the first place, the three stop piers were built up to the springing level of the arches. A trestle was then fixed upon each of them up to the longitudes of the old viaduct, and was securely wedged to them, thus dividing the old structure into five parts, so as to minimise the risk during reconstruction. The work was then dealt with in sections between the stop piers. The intermediate piers were carried up to springing level and the centres fixed. Owing to these having to be built between the timbers of the existing viaduct, it was necessary to erect each one of them in pieces in place. The laggings were then fixed for about 4ft. on each side of the piers, and the piers raised to above springing level, about 4ft. of the arch being turned on each side of the pier to enable this to be done.

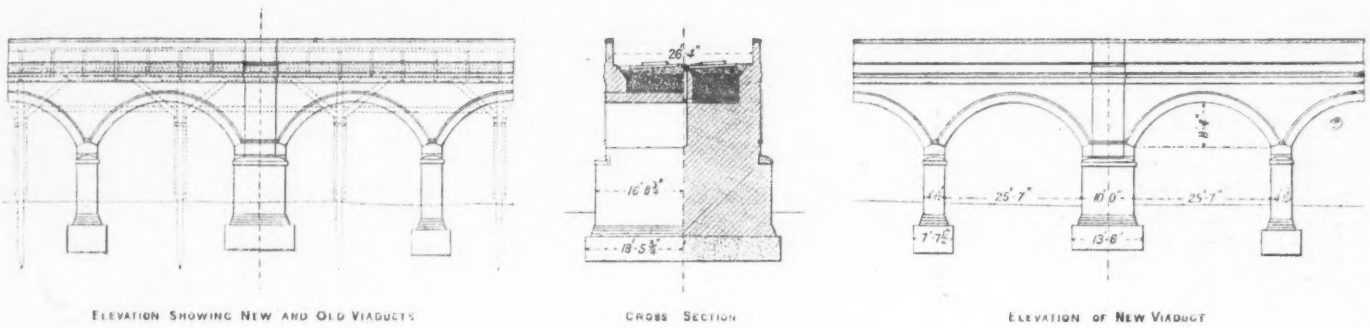


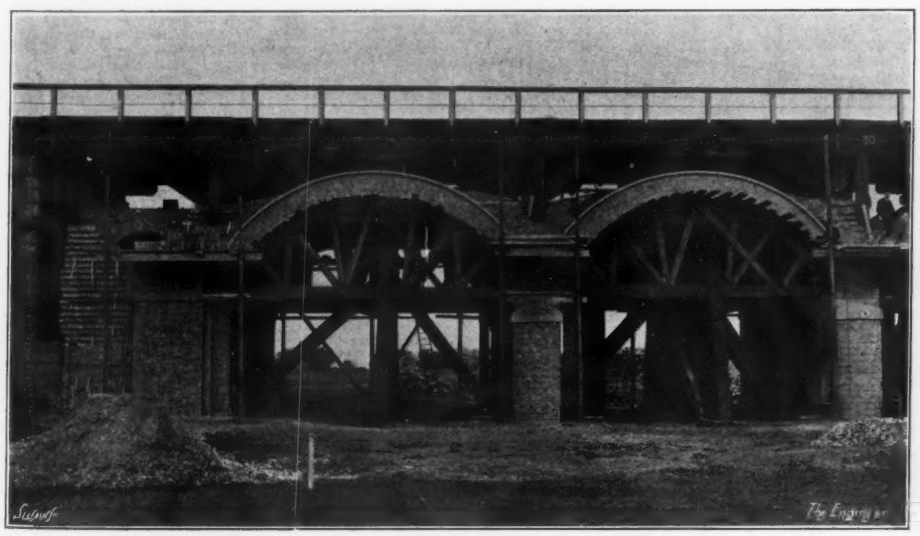
ONE OF THE STOP PIERS

Trestles were then fixed on the top of each pier in a similar manner to that on the stop piers. The struts from the piles of the old viaduct were then taken out and temporary struts fixed in the opposite direction from the new brick piers to the longitudinals. This enabled the lagging to be put on over the rest of the centres, the only portion of the old viaduct coming through the lagging being the piles. The arches were then turned in the usual way, leaving the piles passing through them. So soon as the haunches were filled up and sufficiently set to bear the weight, the whole was paved with blue bricks; packings were then put under the longitudinals so as to bring the weight on to the arches. The tops of the piles were sawn off underneath and withdrawn from the brickwork, the holes they had occupied being filled up.

DETAILS OF THE OLD AND NEW RADCLIFFE VIADUCTS







ARCHES OF THE NEW VIADUCT

The parapets having been built, it was necessary to arrange to take out the old longitudinals, crossheads, and struts, and the planking of the floor from the top of the arches, and to fill up the space they occupied up to formation level. As one road had to be occupied for traffic during the whole of the time, it was necessary to arrange so that half of the viaduct could be filled up at one operation. A dry rubble stone wall was therefore built in the 6ft. way, nearly up to the planking of the old viaduct. Holes were cut in the planking, and as much filling of rubble stone and spent ballast as possible was tipped, care being taken not to fill in the old timbers so that they could not be readily removed. When this was completed, single line working was put into operation on a Sunday, the old timbers were taken out, and the remaining space filled up. The bottom ballast of broken slag was then laid and the permanent way, which is of the Great Northern latest type, put into place.

The operations of taking out the old structure and filling up the arches, and laying in the new permanent way occupied six Sundays, during which time single-line working was put into operation. With these exceptions, traffic was not stopped over the viaduct during the period the work was in hand, beyond permanently slacking the trains to a speed of 5 miles per hour, so that sufficient control might be retained over them in case of accident, but it was not found necessary to bring any train to a standstill whilst the operations were in hand. The work was of an onerous nature affecting the security of the railway traffic at this place, and was carried out under the administration and direct supervision of the district engineer and his staff, working to the instructions of Mr. Alexander Ross, the chief engineer of the Great Northern Railway.

PAISLEY GASWORKS EXTENSIONS.

THE Gas Commissioners of Paisley have obtained a Provisional Order empowering them to spend about £60,000 for extending and equipping the burgh gasworks. Meantime improvements have been principally confined to the erecting of retorts and the providing of coal bunker accommodation, which will entail a cost of £6870.

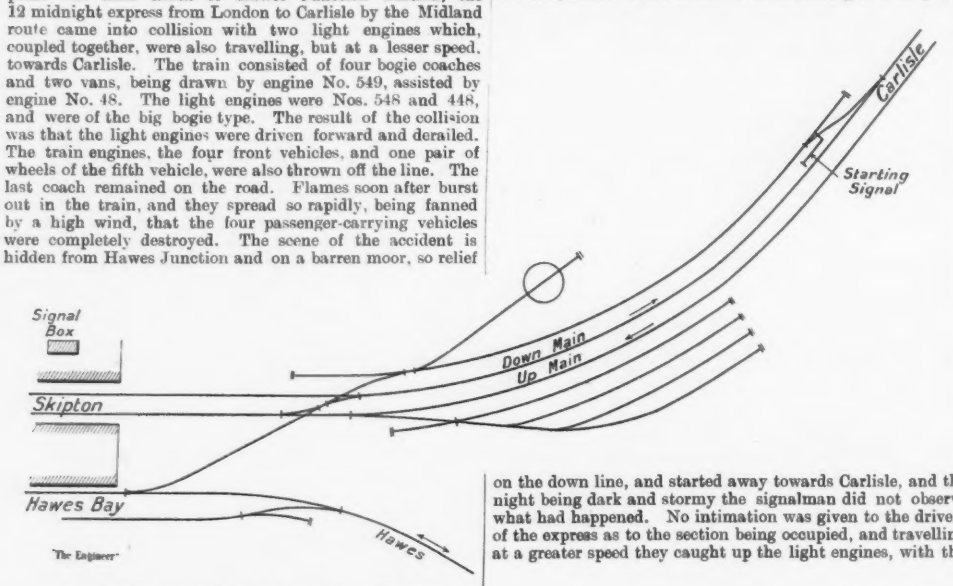
New retorts, to the number of 80, have been added, which will bring the total number up to 416, an increase of 26.31 per cent., and give a total reserve of 36.84. By the time this reserve has been reduced to a safe limit it is proposed to instal a carburetted water gas plant, which will be equal to another 100 retorts. In addition to, and as part of the retort extension, four coal bunkers, each holding 32 tons of coal, together with the necessary gravity bucket conveyors for filling them, have been erected. Two of the four bunkers are in a new retort-house, erected in 1899. An addition has also been made to the coal storage.

By the erection of the new retort-house the storage accommodation has been reduced by 1200, and it has been found necessary to erect new stores. These have been put on the east side of the works, and by next year, when the storage space has been completed, there will be a capacity for 3300 tons, which will bring the total accommodation up to 9500 tons, equal to 41 days' consumption, on the basis of last year's requirements. If, however, the consumption is based on the demands for gas this winter the addition would be equivalent to 38 days. The proposed carburetted water gas plant when completed will be capable of producing the maximum permissible proportion of gas, to the extent of 1,500,000 cubic feet per day. The carrying out of the general extensions, for which the £60,000 borrowing powers were received, will extend over seven years.

YORKSHIRE LOCAL SECTION OF THE INSTITUTION OF ELECTRICAL ENGINEERS.—The third general meeting of the session will be held at the University, Leeds, on Wednesday, 11th January, 1911, when the chair will be taken at 7 p.m. An address will be given by Dr. Henry Stroud, member, on "Radio-telegraphy," with special reference to the experimental wireless telegraphy station at Armstrong College Newcastle.

THE MIDLAND RAILWAY DISASTER.

JUST before six o'clock on Saturday morning last, at a point one mile north of Hawes Junction Station, the 12 midnight express from London to Carlisle by the Midland route came into collision with two light engines which, coupled together, were also travelling, but at a lesser speed, towards Carlisle. The train consisted of four bogie coaches and two vans, being drawn by engine No. 549, assisted by engine No. 48. The light engines were Nos. 548 and 448, and were of the big bogie type. The result of the collision was that the light engines were driven forward and derailed. The train engines, the four front vehicles, and one pair of wheels of the fifth vehicle, were also thrown off the line. The last coach remained on the road. Flames soon after burst out in the train, and they spread so rapidly, being fanned by a high wind, that the four passenger-carrying vehicles were completely destroyed. The scene of the accident is hidden from Hawes Junction and on a barren moor, so relief



ARRANGEMENT OF LINES AT HAWES JUNCTION

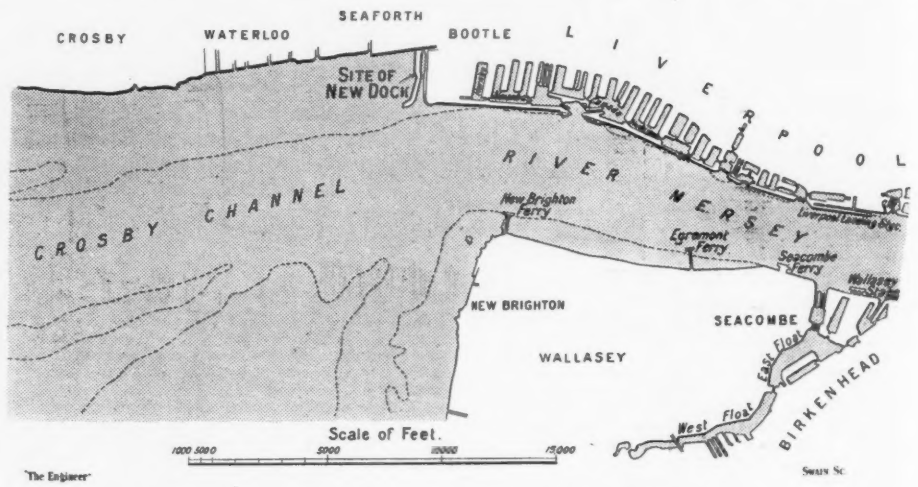
was slow in coming. An engine, however, arrived in time to draw away the last van and to drag out of danger the other van, which was partly derailed. The number of passengers killed by the collision or subsequently burnt is known to be nine, besides an infant; but, possibly, the death roll may turn out to be higher. No passengers are reported as seriously hurt, and, although all the enginemen were badly knocked about, only one is detained in the hospital.

To understand the situation it is necessary to remark that at Aisgill signal-box, three miles north of Hawes Junction, is the summit—1167ft. above sea level—of the Settle and Carlisle Railway. Trains from the North approach Aisgill on a gradient of 1 in 100 for fifteen miles. Seven miles south of Hawes Junction is Blea Moor tunnel, which is approached by trains from the South, also on a gradient of 1 in 100 for fifteen miles. Between Aisgill and Blea Moor is a tableland of about ten miles, and on this stretch is situated the station of Hawes Junction, which has an engine turntable. Up trains, *i.e.*, from Carlisle, that have been assisted by a pilot stop at Aisgill, unless the pilot be going through, and the assisting engine is detached and it is placed in a siding on the up side. Later it proceeds to Hawes Junction, is turned on the table there and returns light to Carlisle. The pilot engines of down trains are detached at Hawes Junction.

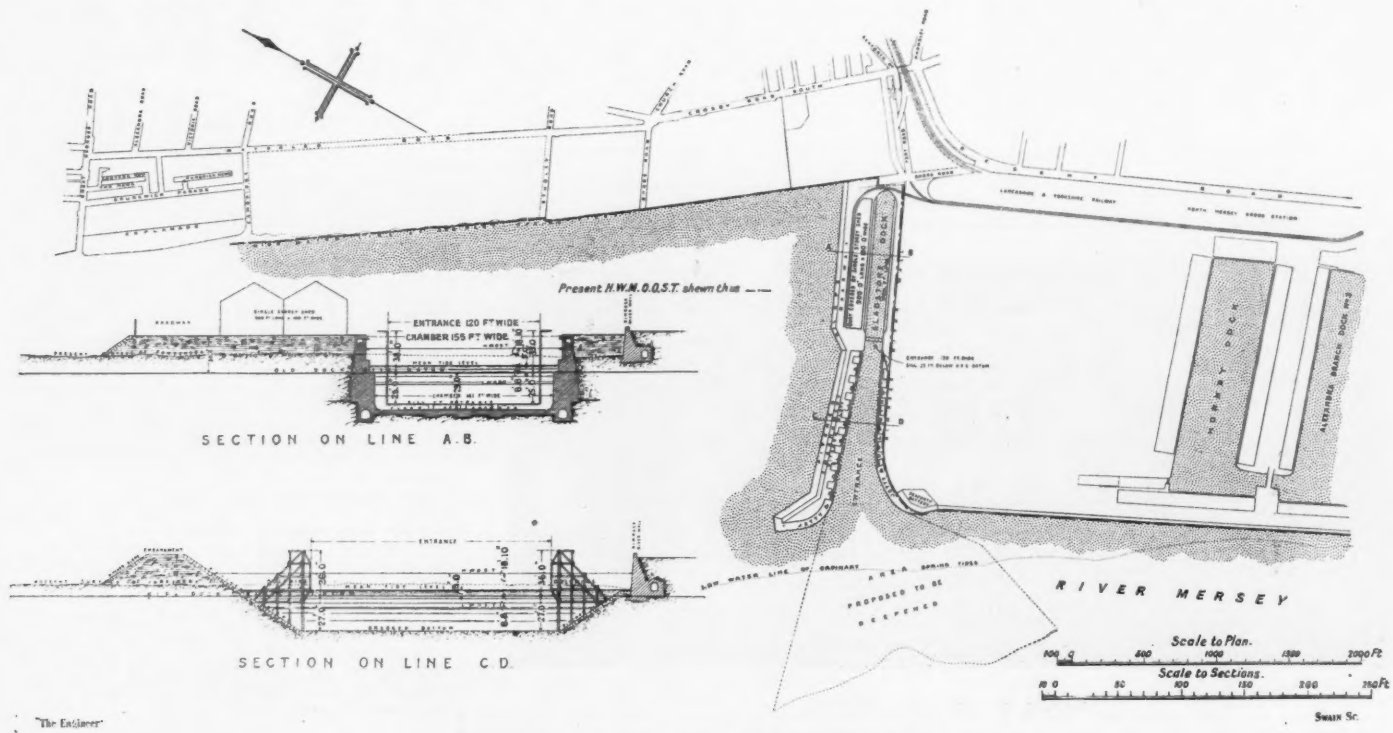
That station is then, at times, a busy place, and this was particularly so on Friday night last, owing to the extra traffic due to the Christmas holidays. Early on Saturday morning there were seven engines waiting to be turned, of which two were to go back to Carlisle. These latter, when reversed, had to wait for the passage of some excursion trains and the 12 midnight express from London. They stood on the Hawes bay line, seen in the diagram, and after a down excursion passed the signalman wanted the Hawes bay for some of the other engines, so called out the two that were waiting to go to Carlisle on to the down main line. Whilst they were standing there the signalman was busy with manœuvring the other engines, and when offered the express he forgot the two on the down main line. He then lowered his signals for the express, and among these was the starting signal. The men on the light engines, when the signal was lowered, assumed that it was for them, seeing that they were on the down line, and started away towards Carlisle, and the night being dark and stormy the signalman did not observe what had happened. No intimation was given to the drivers of the express as to the section being occupied, and travelling at a greater speed they caught up the light engines, with the sad result already related. The line throughout here is on reverse curves and in tunnel and cuttings, and these gave the express men no opportunity of catching sight of the light engines in sufficient time to pull up, as would perhaps have been possible had the line been straight. Major Pringle commenced his inquiry on behalf of the Board of Trade on Monday, and later in the day the coroner's inquest was opened, the latter being subsequently adjourned until yesterday (Thursday).

THE LEVIATHAN DOCK FOR LIVERPOOL.

THE announcement made a few days ago of the placing of the contract for the huge Cunarder with John Brown and Co., Limited, coupled with the report from Belfast of lack of accommodation for fitting out the Olympic, lends special interest to the work of constructing the new great dock by the Mersey Docks and Harbour Board which has been commenced. By the courtesy of Mr. Anthony G. Lyster, the Dock Board's engineer, we are enabled to place before our readers illustrations which give a good idea of the capacity of the new dock and its situation with regard to the existing system. The dock will be situated immediately north of the Rimrose River Wall, Seaforth, and will be 1020ft. long—or nearly 140ft. longer than the Olympic—and its entrance will be 120ft. wide, while the sill will be laid at a level of 25ft. below the old dock sill. As will be observed from the transverse sectional views given herewith, the construction of the dock will be such that it will be available when specially required as a graving dock, and with this object in view it will be provided with a pumping plant of sufficiently large capacity to enable it to be quickly adapted to repair and overhaul work. The floor will be laid in concrete at a level of 29ft. below the old dock sill. It will have a centre line of keel blocks and side lines of blocks where necessary, entrance caisson, &c. There is to be a single-storey shed 900ft. long by 100ft. wide on the north quay, with the necessary paving, roadway and railway sidings. For the handling of cargoes there will be four movable cranes with a range of travel extending the complete length of the shed. The entrance channel at its mouth will be 400ft. wide, narrowing down to 120ft., and will be dredged to a depth of 27ft. below the old dock sill, with pitched slopes and dolphins. With a 10ft. tide—the lowest likely to be met with—a minimum depth of 35ft. of water will be available. The operations now going on in connection with the construction consist of dredging the entrance and the removal of spoil from the south-west corner to the north side foreshore to form the embankment, the level of which will be 30ft. above the old dock sill Datum line.



THE PORT OF LIVERPOOL, SHOWING THE SITE OF THE NEW DOCK



PLAN AND SECTIONS OF THE NEW DOCK TO BE CONSTRUCTED AT LIVERPOOL

The work is being carried out entirely by the Mersey Docks and Harbour Board, and is estimated to cost £500,000.

RAILWAY MATTERS.

THE British Consul at Naples reports that a Bill has recently been submitted to the Italian Chamber of Deputies providing *inter alia* for the purchase of 8000 railway goods wagons at a cost of £2,240,000, and empowering the State Railways Administration to obtain wagons from Italian makers on the hire purchase system.

THE strength of track fastenings has been investigated by an engineering board representing the city of Chicago and the local traction companies, and the results show that screw spikes have far greater holding power than ordinary spikes. For example, the holding power of screw spikes in untreated oak was about 9000 lb. and that of spikes was 5900 lb. The figures were 7000 lb. and 3500 lb. for untreated yellow pine, 6200 lb. and 3500 lb. for short leaf pine treated by the zinc chloride process, and 5500 lb. and 2900 lb. for treated loblolly pine.

IN Russia, particularly in the south-east, brine is very largely used for impregnating railway sleepers and telegraph poles. Though not so effective a preservative as creosote, brine is considerably cheaper. Special impregnating basins have been constructed, in which the sleepers are placed in rows and allowed to remain in the brine for from three to four months. The brine contains 164 grammes of saline matter (136 grammes of sodium chloride) per litre. The brine does not penetrate far into the wood, but the sleepers absorb from 70 to 100 per cent. of their weight.

THE *Tramway and Railway World* states that the official tramway traffic returns of 64 of the principal undertakings of the United Kingdom for the week ending December 17th amounted to £200,220, or £16,510 more than for the corresponding week last year, while the track mileage was 2505, or 191 more than for the corresponding week. The receipts were at the rate of £79 18s. 7d. per track mile, an increase of 10s. 9d. per mile as compared with last year. The receipts from the London County Council and Liverpool Corporation tramways included in the above return are for a preceding week, as they issue their returns later.

SOMEWHAT of a novelty in its way is the decision of of a Pennsylvania inter-urban traction system to establish a height limit in place of the usual age limit for determining children's fares. According to *Electric Traction Weekly* this company has had a gauge line painted round the interior of the car at a height of 45in. above the floor; in case of dispute the youngster "heads" the line, and if taller than 45in. he pays full fare. Our contemporary considers that this is a much fairer proposition than the age limit, because the cost of handling a person is dependent upon size and space occupied, and height is a better index as to weight than age, even if it were possible to verify the latter.

IT is instructive to find the London, Tilbury and Southend Railway Company moving in the matter of electrification. The proposal, states the *Electrical Engineer*, is to apply to Parliament for powers to increase capital by about one million sterling, to be spent on power stations and sub-stations, electrification of the line, and the purchase of new rolling stock. The company has already had actual experience of electricity, as its system is electrified as far as Barking, the District Railway Company running over this section from the City by arrangement. It is hoped to accelerate the service and thus attract more traffic, which would be handled more economically than by steam traction.

IT is reported that the Government of Panama have contracted with the Panama Railway Company to build a line from the city of Panama to David, the capital of the province of Chiriqui. The distance is about 274 miles, and it is expected that the route surveyed by the Intercontinental Railway Commission in 1893 will be followed. The road will traverse a rich district and will be an important factor in the development of a large and fertile section of the Republic. The Panama Railway is also to build for the Government a standard gauge railway, connecting with the Empire in the Canal Zone, and Chorrera, Penonome, Nata, Agua Dulce, and Santiago in the Republic of Panama, with a branch line from or near Santa Maria to the town of Pedasi, in the province of Los Santos, and a branch from the foot of the Divide or Cordillera to Anton, in the province of Coele.

THE Bill to incorporate the North Yorkshire Dales Railway Company has now been deposited for introduction into Parliament next session. Under it powers are sought to construct a railway over 33 miles in length from Threshfield to Scorton. The railway, which is really an extension of the Yorkshire Dales Railway, is proposed to be commenced by a junction with that railway at its termination at Grassington, and will terminate by a junction with the Richmond branch of the North-Eastern Railway at Scorton Station. A further connection with the North-Eastern system is proposed to be made at Leyburn, where a connection will be made with the Northallerton and Hawes branch of that railway. The running powers asked for by the new company will cover the right to run over the whole of the Yorkshire Dales Railway, over the Midland Railway into Skipton Station, and over the North-Eastern Railway into the stations at Darlington, Middlesbrough, Leyburn, and Northallerton. The capital proposed to be raised for the construction of these lines is £495,000.

IT is reported in the *Railway Times* that a project is under consideration in the Glossop and Marple district of the High Peak for the revival of the tramway scheme put forward by a group of Manchester gentlemen some years ago for a line along the Glossop-Marple road, with the important modification that the present line is intended to be a mono-rail tramway. The Glossop terminus will be situated near the Plough Inn. Dinting—at which point an exchange of traffic will be made with the existing Glossop and Hadfield Tramways—the route from thence being through Gamesby, Charlesworth, Chisworth, Ludworth, Lane Ends, and Comstall road to a terminus at Marple Bridge, within a few minutes' walk of Marple Station. It is intended to apply for powers to carry goods and minerals as well as passengers, and as the coal and gannister mines at Chisworth—which have recently been reopened—are situated directly on the line of route, it is anticipated that considerable commercial developments will accrue to the district from the establishment of much-needed transit facilities between the town of Glossop and the Sheffield and Midland Joint Railway at Marple. The line will be about 5½ miles long.

ACCORDING to the *Electrical Review*, it is intended to introduce electric traction in the near future on the Mont Cenis railway, as well as on the Giovi line (Pontedecimo-Bussala), through the Ligurian Apennines. The Italian State Railway authorities have erected, for the working of the Giovi railway, a steam power station near Genoa, whilst the supply of current for the operation of the Mont Cenis line will be obtained from the Chiomonte hydro-electric works, belonging to the city of Turin. Another line between Piemont and Liguria—the Ceva–San Giuseppe–Savona—is to be converted to electric traction, and the 14,000 kilowatts required for its working will be furnished by the Società Riviera di Ponente R. Negri. A contract has also been concluded between the State Railways and the Adamello Company for the delivery of 2000 kilowatts, which is to serve as stand-by for the State Morbegno power station when the Milan-Lecco line, which is a feeder of the Valtellina Railway, is electrified in the near future. The Dinamo Company, which furnishes power to the Swiss Federal Railway Administration for the operation of the Simplon railway, is also to supply energy to the Italian State Railways for the working of the Varesini lines, when the steam power station at Tornavento, which has high costs, owing to the difficulties incidental to the provision of coal, will be shut down. It is also intended to employ electric traction in the south on the Naples-Avellino railway, as well as on a number of secondary lines closely associated with the Società Italiana A.E.G.-Thomson Houston.

NOTES AND MEMORANDA.

IN order to illustrate the possibilities of electric light for exterior illuminating, the Denver Gas and Electric Company has outlined its building with electric lamps. The work has been done very cleverly and artistically, so that the lighting does not merely represent an outline of the building, but emphasises the decoration of the building, giving it at night an exceedingly attractive appearance. Thirteen thousand electric lamps are thus used, and their combined candle-power is 200,000.

AT a recent meeting of the Lancashire Section of the British Association of Managers of Textile Works an interesting address on "Exhaust Steam" was delivered by Mr C. C. Richards. The lecturer first mentioned that the use of waste steam meant, in most cases, the adoption of the electric drive, and that the extreme simplicity, reliability, low first cost, and almost negligible running costs obtained by the installation of a low-pressure turbine plant rendered it eminently suitable for the generation of electricity. The introduction of the electric drive meant that in most cases a radical change would have to be made in existing conditions.

A WRITER in an American building magazine says: "I discovered many years ago that wood could be made to last longer than iron in the ground, but thought the process so simple that it was not well to make a stir about it. I would as soon have poplar, basswood, or ash as any other kind of timber for fence posts. I have taken out basswood posts after they have been set for seven years, and found them as sound when taken out as when first put in the ground. Time and weather seemed to have no effect on them. The posts can be prepared for a cent or two each. This is the recipe: 'Take boiled linseed oil, and stir in pulverised coal to the consistency of paint.'"

FOR the deposition of concrete in the construction of the Gatun Locks on the Panama Canal, special cableways have been erected capable of being worked at the speed of 2500ft. per minute. The span between the supporting towers is 800ft., and twenty complete journeys per hour were guaranteed by the makers. The carriages are operated electrically, and controlled by one attendant for each strand. A month or two ago the carriages on two strands of one cableway made twenty-five journeys in one hour, each of them depositing about 50 cubic yards of concrete. The total amount of concrete to be handled by the plant is 2,000,000 cubic yards approximately.

IN a paper read before the Engineers' Society of Western Pennsylvania on November 16th, Mr. P. McNiven Bennie, of Niagara Falls, reviewed the history of the development of electric furnaces. He stated that the electric furnaces now working in the United States would produce a total of 125,000 tons of steel during 1910, so that the process could no longer be considered experimental. He claimed that although the electric furnace would not replace the modern open-hearth steel furnace or the Bessemer converter, yet it would become a serious competitor of the present crucible process for making high-grade steel and would create a new metallurgy which promised to produce vast changes and improvements in steel making.

WHEN the mercury vapour lamp was invented, and it was discovered that the light was lacking in red rays, it was thought by the uninitiated that the light could be improved by the use of red glass about the lamp. This, of course, was impossible, for the reason that red glass acts merely as a filter of the light passing through it, cutting off all rays except the red. As there were no red rays in the mercury vapour lamp, the effect of putting red glass around it was to cut off practically all the light. According to the *Scientific American*, Dr. Peter Cooper Hewitt, the inventor of the lamp, has recently devised a means for adding red rays to the light emitted by the lamp. He uses a reflector coated with fluorescent material, which is of such a character as to transform the wave length of certain rays falling upon it, so that red rays are reflected. The fluorescent material is painted on sheets of cardboard, which may be removed from the reflector frame when they show any deterioration, and be replaced with fresh sheets.

IN a paper read before the Manchester University Engineering Society, Mr. A. C. Wilson discusses the evidence available concerning the use of reheaters for the receiver between the high and low-pressure cylinders of steam engines. His conclusions are that with saturated or wet steam a reheater is useless, and that instead the water ought to be carefully drained off before entering the low-pressure cylinder. Where the steam is initially superheated to a considerable extent, a reheater using boiler steam may be useful in some instances because it slightly superheats the steam entering the low-pressure cylinder, and superheated steam is more efficient than wet steam in excess of the theoretical improvement. By passing the reheated steam to the high-pressure cylinder very highly superheated steam can be used without having an excessive temperature in the cylinders, and at the same time a fair degree of superheat in the low-pressure cylinder is ensured. Mr. Wilson believes that this last case gives the best results with reheaters, but a good deal depends upon circumstances. Generally, a reheater is a useless complication, and it is only in special cases that its adoption need be considered at all.

ON December 12th a lecture on "Thorium" was delivered at Glasgow University by Mr. F. Soddy. The lecturer explained that thorium had a large application in the manufacture of incandescent gas mantles, and was one of the primary radio-active elements. There was a possibility of increasing the thorium minerals intensely, giving active products of the same nature as radium. There were two kinds of thorium—mezzo and radio—discovered by Dr. Hahn. Mr. Soddy stated that thorium had a useful life of about eight years. Dr. Auer von Welsbach was the discoverer of its application to incandescent mantles, in which a mixture of 99 per cent. of thorium and 1 per cent. of ceria was used. Mr. Soddy showed these two elements in their separate state, and demonstrated that they gave no light. He gave statistics supplied by Mr. Langlands, of the Glasgow Corporation Gas Department, with regard to the use of incandescent gas mantles in the lighting of the streets of the city. The number of mantles used per annum in Glasgow was 200,000, giving light sufficient to illuminate the road from London to Glasgow. About nine and a-half mantles were used per gas lamp in the Glasgow streets every year, and the quantity of gas consumed per mantle averaged 1000 cubic feet.

AT the opening meeting of the Birmingham Metallurgical Society, Professor Thomas Turner delivered his presidential address. Speaking of the diffusion of metals, he said it was formerly the custom to divide metals into those which were volatile and those which were non-volatile, but such distinction no longer existed, since, in the electric furnace, all metals could be converted into vapour. Metals resembled water or other liquids in that they evolved vapour at temperatures well below their melting point. The vapours of metals obeyed the ordinary law of gaseous diffusion, and even in solid metals, when near their melting point, considerable internal admixture or diffusion might take place. As examples of this, Professor Turner mentioned the case of base bullion, which, in consequence of the complete admixture of the metals, proved to be uniform in composition, and so also were the alloys used for coinage purposes. In the annealing of cast brass, which, as first made, was variable in composition, the diffusion of the zinc led to great improvement in the uniformity and texture. The formation of silicates by heating together finely powdered materials well below their melting points was another important example of diffusion which, doubtless, had its application in the fire-brick trade and the china industry. The conversion of iron into steel, with the absorption of carbon, was also cited as an instance of the diffusion of an element in a metal at a temperature below the melting point.

MISCELLANEA.

THE Glasgow Corporation have adopted a resolution stating that a new bridge over the Clyde, west of Jamaica-street, is necessary, and remitting the matter to the Sub-committee on Cross-river Communication to confer with the Clyde Trustees.

THE British Trade Commissioner for South Africa reports that an exhibition of fencing material is to be opened by the Agricultural Society of Middelburg, Cape Province, next March. Applications for space will be received up to February 10th.

MANY complaints having arisen through the deposit of naphthaline in the Widnes street mains and service pipes, the gas and water engineer commenced, in June last, to wash the gas with water-gas tar. According to the *Chemical Trades Journal*, some improvement was effected, but matters became worse in October. Finally, a special preparation known as Solvene, a distillate of coal tar, was substituted for the water gas. Since its use was commenced there has been a falling off of about one-third of the number of complaints.

THE Department of Mines, Canada, has issued a report of analyses of ores, fuels, &c., made in the chemical laboratories of the Geological Survey during 1906 and 1907, and of the Mines Branch of the Department of Mines in 1906, 1907, and 1908. With the exception of twenty-seven rock analyses, the work done is chiefly of practical interest, analyses being given of numerous coals, lignites, peats, and ores of iron, copper, and chromium. The results of seventy-seven gold and silver assays show the wide distribution of the precious metals in Canada. In an appendix a description is given of the commercial methods and apparatus used for the analysis of oil shales.

IT appears from a United States consular report that the exporters of Japanese sulphur in Japan have been approached on the subject of sending this product to the Atlantic seaboard. They are, however, of opinion that there is not the slightest possibility of Japanese sulphur of any description going to the Atlantic coast market, for the reason that it cannot possibly compete with the product of the Sicilian or Louisiana mines. Some years ago, before the Louisiana mines were opened, an occasional shipment of Japanese sulphur was made to the Atlantic coast in competition with the Sicilian product, but this procedure has all been changed since the Louisiana producers began operations. American sulphur exporters in Japan are able to ship to the Pacific coast, and, in fact, that market is largely controlled from Japan. This is mainly due to the fact that sulphur freights from Japan to the Pacific coast are cheaper than from any other producing point.

IT appears, from a note in the *Electrical Engineer*, that progress continues to be made in the acceptance of electricity from the public mains as a motive power in the leading Birmingham industries. In the jewellery trade practically all the power required is, or soon will be, obtained in this way. In the heavier industries the department is able to report a number of inquiries, some of which have resulted in good orders for high-tension supplies. The growth of the electro-plating trade in Birmingham is likely to prove profitable to the public supply. Of late years, Birmingham has become more and more a formidable rival to Sheffield in this industry, and it is estimated that there are now about ten electro-plating firms in Birmingham to one in Sheffield, whilst the number in Birmingham, as compared with ten or fifteen years ago, has multiplied a hundred-fold. Some of the firms engaged in this business take the corporation supply and transform it for plating purposes, while a greater number are customers for power in the ordinary sense.

IF the schemes now under consideration by the Government of Chile for the development of the trade of that country are carried out a sum of about £2,325,000 will be required for public works before very long, and though this is a large sum it is believed that it will quickly be reproductive. The most important projects are in connection with the improvements of communication with Mejillones and Iquique, while other schemes relate to Antofagasta and Arica. As regards Mejillones, the growing volume of nitrate brought down from the interior, together with the important share of the Bolivian traffic which proceeds *vid* this port, render it necessary that a new jetty of considerable dimensions should be constructed for the accommodation of modern vessels. In order to achieve this object it will be necessary to undertake extensive dredging operations, while two years at least must elapse before the completion of the scheme, the cost of which is estimated at about £300,000. There are at present three jetties, two of which have been erected by the Antofagasta Railway, while the third belongs to a local shipping undertaking. These structures can no longer deal adequately with the rapidly growing traffic.

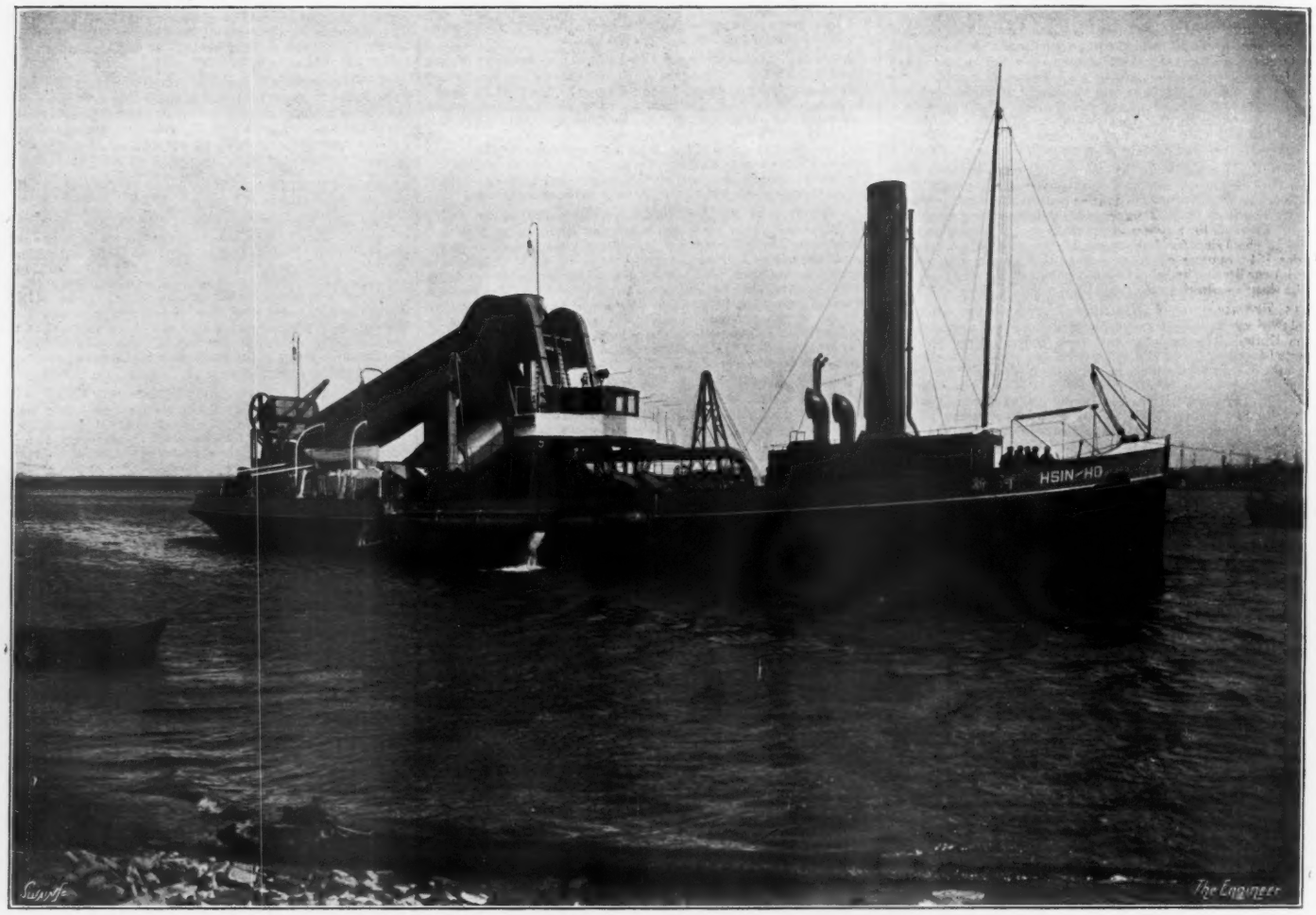
SPLENDID progress has recently been made with the work of placing in position the armoured plates forming the broadside protection of the cruiser Lion at Devonport. The second barbette gun forward has also received the greater part of its armour, and is almost ready for the closing plates. This barbette, which is raised a considerable height above the foremost barbette, being the first of the type to be so constructed at Devonport, will, when complete with its 13.5 guns, be the heaviest twin-gun barbette in existence. The general work on the upper deck continues to make good progress, and the imposing superstructure is beginning to assume a shapely appearance. The under-water work, consisting of the boring out of the main shaft and rudder bearings, is almost completed, and the rudders are well advanced. It is not intended to ship the shafting until the closing stage of the cruiser's completion. Work in both the engine and boiler-rooms is well advanced, and all will be in readiness for the reception of the 70,000 horse-power turbines at an early date. The three enormous squat funnels are nearing completion. As soon as the work of armouring is completed the Lion will be moved out of No. 8 dock under the 160-ton crane, and will there complete the shipment of her turbine machinery and armament of 13.5in. and 4in. guns.

THE scheme of sewerage work which is now being carried out at Toronto at a cost approaching half a million sterling includes the construction of two intercepting sewers, a pumping and treating plant, and a sewer for the disposal of the effluent. According to the *Times*, the sewage tanks are situated at the east end of the city on low-lying land. One of the intercepting sewers, which will be of circular form in brickwork, and will vary from 9ft. 6in. to 3ft. 6in. in diameter, will start from near the tanks and will extend westwards for eight miles. This sewer will be situated at a high level, and will deal with the dry-weather flow by gravity. The other intercepting sewer, placed at a low level, will start from the same place and will continue westwards for five and a-half miles. A large building is to be constructed near the tanks to accommodate the screens for both sewers, four electrically driven centrifugal pumps with a total capacity of 100 cubic feet a second, an auxiliary gas engine, and an electric generator. The scheme provides a partial treatment for the sewage. Twenty-four sedimentation tanks are to be constructed, from which the sludge will be pumped through pipes to Ashbridge's Marsh, which will be enclosed for the purpose. The effluent sewer will be 60in. in diameter and about a mile in length. Two-fifths of this work is being laid with a reinforced concrete pipe and the remainder in steel. The concrete pipe, although cheaper in initial cost, is said to be less satisfactory to lay than the steel. It is being laid in 24ft. lengths, each of which weighs 16½ tons. Metal flanges to be bolted together are provided for the ends. The steel pipe is made in 50ft. lengths and is being laid in two lengths at a time. The work is now about half completed, and it is expected that a portion of the scheme will be ready for use next summer.

TWO NEW DREDGERS

A. F. SMULDERS, SCHIEDAM, BUILDERS

(For description see page 690)



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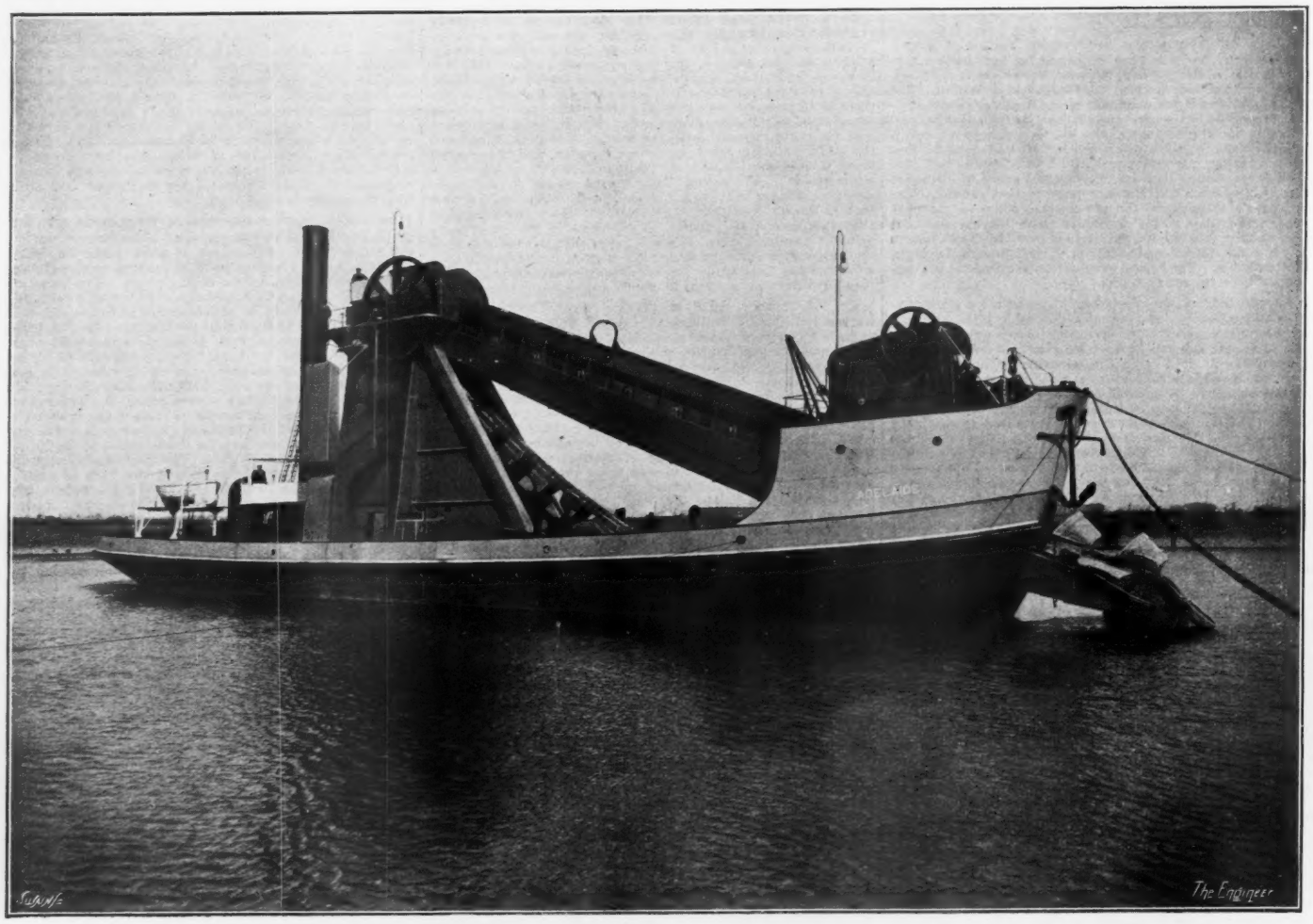

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TO CORRESPONDENTS.

☞ *In order to avoid trouble and confusion we find it necessary to inform correspondents that letters of inquiry addressed to the public, and intended for insertion in this column, must in all cases be accompanied by a large envelope legibly directed by the writer to himself, and stamped, in order that answers received by us may be forwarded to their destination. No notice can be taken of communications which do not comply with these instructions.*

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REPLIES.

A. H. (Birmingham).—You will find nearly, if not all, the particulars for which you ask on page xiii. of the Supplement. The dates given are those of the first engine of each class.

THE ENGINEER.

DECEMBER 30, 1910.

The Output of Naval Ordnance in England and Germany.

EARLY in August we thought it desirable, in the interests of accuracy, to draw attention to the technical difficulties of fulfilling the elaborate claims made in respect of certain foreign ordnance by interested journals abroad. Since then, however, the relative merits of British and German heavy naval guns, and the presumed status of the rival navies, have been continually discussed with such extreme ignorance and vigour by the daily Press of this country, that if the average man in the street is not bewildered it is really surprising. The statements that have recently been made in connection with the adoption of the 13.5in. gun by the British Admiralty, and the consequent delay experienced in German naval construction, are extremely misleading, because we are fully convinced that the German Admiralty knew what was the calibre of the latest British weapons long before the British Press did. That the significance of the change was immediately realised is much more doubtful. It is now nearly two years ago since the decision to adopt the 13.5in. gun in the Royal Navy was made, but in all the subsequent correspondence the weapon continued to be referred to as a "12in.-A," until well on into this year, a subterfuge which, perhaps, intensified any doubt as to the certainty of the change contemplated. As long ago as February last year we pointed out that naval artillery had to some extent receded relatively to protection, and summarised the position as being a question of whether a greater number of guns of the same calibre—at that time the 12in. 50-calibre weapons—should be carried, or if a larger calibre should be introduced. The conclusion expressed, as the result of a careful consideration of the position, and which was such as might have been made by any specialists in warship architecture, was that the latter alternative would be selected. That it was effected without Press comment is certainly a tribute to Admiralty reticence. Secrets, however well maintained, do leak out, but unless conclusive evidence is forthcoming the suggestion is useless, and while we have excellent reasons for stating that the existence and possible acceptance into the Royal Navy of the larger calibre weapons was known abroad at least eighteen months ago, there is deductive evidence that the influence of such weapons on future programmes was totally unappreciated.

Before considering the development in weapons, it is convenient to recall the history of recent battleship construction in this country and in Germany. That we are forced to consider Germany in comparison must not be taken as attributing any hostile intent on her part to any other countries whatsoever; it is simply because, as our nearest neighbouring and most scientific competitor, it is possible to obtain a better comparative idea of our own position than could be obtained by reviewing British progress in the light of that of other countries. The year 1905 contained a great step as regards naval architecture in the building of the Dreadnought. This vessel, with the three Invincible class cruisers, formed part of the 1905-6 Naval Estimates. Those of 1906-7 contained the three battleships Bellerophon, Temeraire, and Superb; in 1907-8 the St. Vincent, Collingwood, and Vanguard were ordered; in 1908-9 the Neptune and Indefatigable alone were ordered; but in 1909-10 the Collingwood and Hercules, ordered early in the year, were followed later by the Orion and Lion; the Naval Estimates of 1910-11 contained the four contingent ships Monarch, Thunderer, Conqueror, and Princess Royal, ordered in April, with three others and two colonial cruisers. To summarise these, between April, 1905, and April, 1911, twenty-five vessels have been ordered in six years, involving an armament of no less than one hundred and forty-eight 12in. guns and eighty-four 13½in. weapons. That is, since the ordering of the Dreadnought, Woolwich, and the British armament companies—Armstrongs, Vickers, and the Coventry Ordnance Companies—have had orders to supply no less than two hundred and thirty-two of the heaviest guns and their mountings for the Royal Navy only. Added to these, there have been orders placed for some fifty Japanese 12in. guns, for twenty-four Brazilian 12in. and twelve 14in. weapons, together with numerous reserve guns for the British and foreign navies, making a total of between fifty to sixty guns a year.

On the German side we find during the same period—viz., from April 1st, 1905—the following ships ordered:—Schlesien and Schleswig-Holstein in 1905, each carrying four 11in. 40-calibre guns; Nassau and Westfalen in 1906, Posen, Rheinland, and Von der Tann in 1907, all five carrying 11in. 45-calibre guns; Helgoland, Thuringen, Ostfriesland, and Moltke in 1908, with 12in. guns. The 1907 vessels are all in commission; none of the 1908 boats will be commissioned till the latter end of next year at the earliest. Of the 1909 vessels, the Oldenburg is already well advanced at Dantzig, but the Ersatz Hildebrand at Kiel, and the Ersatz Heimdall and cruiser "H" at Hamburg, are still some months from even being launched. All these vessels are stated to carry 12in. weapons. The 1910 ships are not yet laid down, in spite of having been ordered as long ago as April last, and they are expected to carry a larger gun. Both the 1909 and 1910 ships were entirely retarded for nearly three months owing to the shipyard strike in Germany, which occurred during August, September, and October of this year. During these six years, therefore, the Krupp Company, which supplies all the German naval artillery, has had orders—giving the four 1910 ships credit for ten 14in. guns apiece—for less than two hundred weapons of 11in., 12in. and 14in. calibre, apart from reserves and very few foreign weapons of this type, that is about thirty-five guns a year, for the nineteen ships ordered.

Taking the sequence in which the German weapons must obviously have been ordered, we find eight guns in 1905, twenty-four in 1906, thirty-two in 1907, increasing to forty-six in 1908 and again in 1909. Now, the weights as published by the manufacturers are for the 45-calibre 11in. guns 36 tons, and for the 12in. 45-calibre 46 tons. Consequently, whereas thirty-two 11in. weapons were required for the Posen, Rheinland, and Von der Tann in 1907, forty-four 12in. were needed in 1908, involving just double the weight of finished gun steel. The same quantity was apparently required in 1909, but this year, if the 14in. gun is really to be adopted, the weight will again be practically doubled, an increase in steel production of four times the quantity of three years ago. It is a big output to ask of any steel works, however ready it may be to extend. Is it possible that it has not been found practicable to cope with such extraordinarily rapidly increasing demand? Some of the 1908 ships are still waiting for the delivery of their gun mountings, whereas one of the British ships is already in commission and the other has just completed her trials. That is to say, the gun output that was demanded of British builders has been well within their resources, and that without any abnormal pressure of work, largely due perhaps to the greater regularity of output required and better facilities for extension owing to the wider distribution of the various steel works and machine shops involved. Perhaps, also, the coming of the bigger gun was foreseen in this country at an earlier date, but in any case such delay as has occurred in the completion of the German ships is only partly due to the strike, and only partly to the gun question. Steel works capacity of output regulates the latter: it is impossible to double and then quadruple the output at a few months' notice; extensions must be made to more than machine shops, and steel works developments involve much greater cost and time to execute. Herein has lain the difficulty of arming the German navy, and the increased weight of armour required has accentuated it. Again, the guns are only one feature of a ship. The design of their mountings is even more important. German artillerists had to commence four twin 11in. mountings in 1905, twelve in 1906, sixteen 12in. in 1907, twenty-three of the same type in

1908, and again in 1909. Now, for the 1910 vessels no less than forty even larger mountings are required. Such a totally abnormal increase of manufacturing capability is not a matter to strike the uninitiated observer, but it is one that is of stupendous importance to a works. However far-sighted the managements may be, the virtual quadrupling of capacity for such a special type of output in four year is most difficult to arrange, and if delay has occurred it is hardly surprising. We referred to the main differences between the "wire-wound" and solid steel guns at length in August this year. At that time much foreign criticism was being levelled at our naval weapons in respect to both stiffness and durability. Whether the latter bears any relation to the system of construction is very doubtful. In the German case, such durability as has been obtained is said to be largely due to the use of nickel-chrome steel inner tubes. This is certainly excellent material, but it is not by any means unknown in other countries. These tubes are very costly forgings, and, together with the "outer A" tubes which envelop them, are among the most difficult pieces of work a steel works has to encounter.

Altogether there are some 350 12in. and 13½in. guns in the Royal Navy, many of which through length of service or more frequent use are already well worn. These guns are changed at occasional intervals and the guns are either re-lined or exchanged—a somewhat tedious process. The life, of course, varies considerably; some authorities place it at about 140 rounds, others even as low as 100. But whatever it is, these weapons should be, and are, as a matter of fact, maintained in service in a condition nowhere approaching their limit. In war time it will be no easy matter to replace them. A reserve of guns is excellent in theory, but in practice the difficulty will be to get at the ship to replace them. Probably a capital unit is better with the fleet, even if her big guns are detrimentally worn; it may not be possible to spare her from active service sufficiently long for dockyard hands to take out and replace a 60-ton gun—no light task at any time. There is a big floating reserve of guns always available from incompleted or other damaged ships; but this is a case of cure. Prevention of the necessity of change lies in always maintaining them in a state when a protracted action would not result in completely spoiling the inner tube. The greatly improved accuracy of shooting in recent years has rendered a large percentage of reserve guns less necessary; when, as recently happened at battle practice, ten successive 12in. shots pierced a target at 10,000 yards, there is obviously not the need of the reserve that the Japanese required during a war in which the big gun hits did not average 10 per cent. Most of these guns, moreover, were the older 35 and 40-calibre weapons, and they were extremely severely used during two years' service, so that there is little need for surprise at their inaccuracy in the latter stages of the war.

A practical limit to gun development, apart from the question of steel works manufacture of gun tubes, seems probably to lie in the length of human vision under ordinary climatic conditions. A dull day, let alone a misty or a wet one, decreases the range of vision enormously. To reduce the present battle practice range for 12in. guns of 10,000 yards would be very dangerous on a fine day; the 13.5in. gun will undoubtedly increase this to about 12,000, but beyond this it becomes difficult to distinguish objects except during the mid-day hours. For the moment a 14in. gun may be dismissed, but the older Victoria and Benbow, or the Italian Lepanto Duilio used to carry 16.25in. and 17in. guns. Such guns may be built again very likely, but they will be of 45 or 50 calibres, instead of only 30, and their effective range will be 20,000 yards. Now, this seems almost beyond practical vision in this part of the world. There is nothing impossible in the gun or ship to carry it, but there is an obvious objection to it if its effective range is beyond the power of even a Zeiss-aided eye. At a shorter range such a piece will be almost invincible; hence, no one will come nearer than necessary, but given the usual North Sea weather ten miles is an abnormally long range.

It is not probable that any increase above 50 calibres will be made for a long time. The quality of the steel is really the direction in which improvements are most likely to be made. Krupps, unlike ourselves who use Siemens-Martin steel, adopt crucible steel entirely for guns, and claim for purposes where reliability is the primary consideration, that it is homogeneous to a degree that cannot be obtained by any other method of manufacture. English gun plants, however, cannot conveniently be altered as regards their existing furnaces, so that the wire-wound system will be continued for the future in conjunction with the previous quality of steel.

The Reformation of Boiler Engineering.

We admire Dr. Nicolson for the persistence with which he attempts to reform boiler engineering. He holds that the practice of making steam as now followed is antiquated and inept. He is prepared to show the world a more excellent way; and failure and rebuffs leave him undaunted. The faith that is in him enables him to support reverses; and if he cannot achieve success, at all events he deserves it. What he writes and does in the way of boiler engineering are interesting and instructive. They deserve careful consideration. It may be easily conceded that Dr. Nicolson is a very excellent example of the results of the highest type of technical education; and it is well worth while to study his methods of dealing with the usual problems of boiler engineering. For him the transmission of heat, the combustion of fuel, the manufacture of steam, are simply matters of mathematical investigation. Each question as it turns up is solved by an equation; and we have statements put forward as demonstrable truths which are enough to make the hair of common boiler designers, makers, or steam users stand on end. We have from time to time put his views before our readers. Quite recently we dealt with Mr. Longridge's report on a Nicolson experimental boiler. It will be remembered that that report would have proved very disheartening to anyone who had not a fair proportion of faith in himself. Dr. Nicolson, however, has been equal to the occasion. He has apparently abandoned the attempt to make the Cornish or Lancashire boiler better, and has produced a new design which he has made the subject of a very clever paper read before the Institution of Engineers and Shipbuilders in Scotland recently. The subject is "Boiler Economics and the Use of High Gas Speeds."

The history of Professor Nicolson's labours is quite simple. He became acquainted with a statement made by Professor Osborne Reynolds as far back as 1874, to the effect that the amount of heat transferred from hot air to a metal surface is almost in direct proportion to the difference of their temperatures and to the product of the speed of movement and density of the air. At first sight it would seem that this simply means that if we double the weight of hot air flowing through a tube we shall double the weight of water which it will evaporate. To Professor Nicolson, however, it means much more than this. It means that if we pass the same weight of gas through a tube at different velocities, the rate of evaporation will augment with the velocities. He says, then, in effect, instead of letting the flame and products of combustion roll languidly through the great flues of a Cornish or Lancashire boiler, compel them to move at a high velocity. This can only be done by contracting the calorimeter of the boiler—that is to say, reducing the cross-sectional area of the flues. But if this is done the friction will be so great that air enough will not get to the fires. Use, then, an exhaust fan, and make a vacuum at the root of the chimney of 15in. to 20in. of water, and the thing is complete. Furthermore, as we shall not now want a high, or, indeed, any particular chimney temperature, let us combine with the boiler an economiser; and if high speed is good for the former, so it must be good for the latter. Contract, then, the calorimeter of the heater, because the fan will deal with the resistance, and employ a good big circulating pump to keep the water going at high speed through very small and long tubes.

It will be remembered that in the first experimental boiler a water drum was put into the flue of a Cornish boiler, which was of so nearly the same diameter that only 1in. of space intervened all round. Through this space the products of combustion had to find their way under the influence of a fan. Unfortunately, this was too much for the drum, which was speedily burned, and then Dr. Nicolson substituted the long fire-brick cylinder, which was in the boiler when Mr. Longridge carried out his tests. Mr. Longridge held that the theory of the boiler was admirable; its practice execrable. For one thing, every time the boiler was inspected the fire-brick drum would have to be pulled out. We now learn from the paper before us that Dr. Nicolson has abandoned the Cornish boiler, as we have said, and has designed a new mechanism for generating steam. To call it a boiler would be perhaps profanation.

We hasten to say that this generator is extremely ingenious. That it complies very fully with scientific indications of what a boiler should be, in the sense that it is intended to absorb the largest possible quantity of heat in any unit of time, per square foot of surface, there is no room to doubt. But, when we have got thus far, it seems to us that we have reached a limit. Dr. Nicolson is left to face the problem of proving that his boiler represents any advance on existing commercial methods of making steam in boilers which are undoubtedly the survivors of the fittest—the result of years of practice in land stationary boilers and locomotives, and of most costly and tedious experiments, in the case of the great army of water-tube boilers in use at sea.

The proportions of the Nicolson generator, its economiser, fan, &c., and the results to be obtained, have all been settled by elaborate formulæ, over twenty-two in number. These, however, depend for their utility on their coincidence with facts. Thus, if surfaces become dirty, the rate of evaporation may be diminished, and so on. But leaving this to be settled in a few years, or months, or perhaps days, let us proceed to consider what the new boiler is like. The description comes in Part VI. of the paper, under the head "Rational Design of Steam Boilers." Hitherto apparently the designs have been irrational. The author now proceeds to show how "by the application of Stefan-Boltzmann's law of radiation, and Osborne Reynold's law of heat transmission, the designing of a steam boiler may be rationally carried out, with the assured expectation that the results actually obtained on trial will be in close accordance with those predetermined by calculation." We may remark incidentally that Dr. Nicolson does not seem to be aware of the fact that the laws of radiation by hot gases are just now in the melting pot, and that without the least knowledge of either Boltzmann or Stefan, designers of irrational boilers secure results on trial which are just what they had predetermined they should be. The high-speed rational boiler consists essentially of three horizontal drums connected by tubes, so arranged that they resemble an L; the horizontal tubes lie along the crown of a furnace; the flame passes from this through openings in a fire-proof wall to a combustion chamber, from which again the hot gas rises through a forest of vertical tubes, uniting the upper and lower drums, and thence flows downward through another forest of vertical tubes uniting two more drums, which is called the economiser. Here they are got hold of by a big exhaust fan, and so sent to the chimney. There are in all five drums. The furnace arrangements are such that we should not be surprised to hear that the bricks "dripped" in the combustion chamber, as they did with the Cornish boiler in the original experiments. Honestly, we have no exception whatever to take to the design of the new boiler as the embodiment of Dr. Nicolson's theories. But there our approval, we fear, must end. The generating tubes are only ⅝in. diameter, with a bore of ⅜in. The economiser or feed heater has tubes only ½in. diameter and ¼in. bore. It must, of course, be understood that circulation is maintained by a rotary pump. We fail to see how dry steam can be made. We should, indeed, anticipate heavy priming. The use of tubes of such small diameter and some 10ft. or 12ft. long will not, we think, commend itself to engineers. We may safely leave the settlement of the endurance of this generator to time.

It may be asked after all in what way is Dr. Nicolson's generator better than its predecessors? Such, for example, as its congeners of the Stirling type. The reply is that for equal powers it is much smaller; also that it is much cheaper to work. Dr. Nicolson compares a "rational high-speed" generator with an ordinary water-tube boiler, each making 10,000 lb. of steam per hour. The first will cost £855 per annum, the second only £695—a saving at the rate of £320 a year per 1000 indicated horse-power installed. As to space, he estimates that in the Lusitania no less than 37 per cent. would be saved by the substitution of his for Scotch boilers. He draws another comparison between the Chilian warship Libertad, fitted with twelve Yarrow boilers, and alternatively with twelve Nicolson boilers, a saving of 565 tons being effected, and the radius of action at 20 knots raised from 3800 to 5100 miles. We have done our best to place Dr. Nicolson's boiler fairly before our readers. If he is successful in producing a steam generator which will satisfy the demands of purchasers in the way he hopes, then he will have done really a new thing in boiler engineering. But he will no doubt be the last man to be surprised if his claims are regarded

with incredulity. Faith in long boiler tubes of small diameter and intensely heated has been worn very thin.

The Midland Railway Disaster.

WHETHER it be only a coincidence or because they have occurred at the season of the year when happiness and good will should especially prevail, it is a strange fact, possibly accounted for by the traffic being heavier then than at any other time of the year and the days darker, that some of the worst railway accidents have happened at Christmas time. Among them are those at Shipton-on-Cherwell—where more deaths occurred than in any railway accident in the United Kingdom, except the Armagh disaster—at Chelford, Wivelsfield, and at Elliot Junction; to these must be added the failure of the Tay Bridge. Now the Christmas Eve of the present year has, on the top of the worst colliery explosion that has occurred in England, been marred by an accident which has created a feeling of horror throughout the land. The collision which occurred on the Midland Railway near Hawes Junction, was in itself serious enough, and probably had fatal results, but the lamentable part of the affair was the subsequent fire, which, we know for certain, led to the loss of three lives, and possibly more. The daily papers have published graphic particulars of what happened to the unfortunate passengers who were imprisoned, and we are thankful that there is no necessity for us to furnish details of these; but elsewhere in this issue we relate the facts that led up to the accident, and the consideration of these is aided by a diagram of the lines in the station.

It is generally admitted that the two light engines were in the section owing to an oversight on the part of the signalman. This is very unfortunate, as two other recent accidents—those at Ormskirk and Willesden—have also been due to errors on the part of the signalmen. Of these that at Willesden may be dismissed, as it was due to the signalman pulling the wrong lever—No. 55 instead of No. 53. At Ormskirk, however, the orginal cause was the same as at Hawes Junction—a light engine, after being admitted on to the main line, was forgotten. We are not yet in possession of all the facts that led up to the Ormskirk collision, and the publication of the Board of Trade report thereon is awaited with some interest. Until it appears we will say no more as to Ormskirk. Judging from the information furnished by the Press, one cannot but be sorry for the unfortunate signalman at Hawes Junction. If the facts are there stated correctly the man has been in the Midland Company's service for twenty-five years, and has had no black marks recorded against him. It has also to be borne in mind that the mistake was made within half-an-hour of the man completing his ten hours' turn of duty, which had been an unusually strenuous time owing to the exigencies of the Christmas traffic, and was also rendered additionally difficult by rough weather. We admit, however, that it may be argued that Hawes Junction, at its busiest moments, is no worse than thousands of other roadside signal-boxes, and that rough weather is not unusual there—in fact, our personal experience is that it is the prevailing condition. But we are led to make this plea for the signalman because of statements in the organ of the Amalgamated Society of Railway Servants that signalmen generally are being strained by too much "speeding up," that there is an excessive amount of returns, reports and "paper," and that inquiries over the telephone give them unnecessary work. How much truth there is in this, and how far the complaints are justified, we cannot say. It must be borne in mind, too, that these statements are quite *ex parte*, and until we hear the other side—a most unlikely happening, as the companies prefer to remain silent—it is not wise to assume that what is said is true. We would therefore leave this part of our subject by observing, in conclusion, that notwithstanding these unfortunate accidents, the record of British railways as to the number of passengers safely conveyed is most remarkable, and this is due in part, if not mainly, to the very high standard of the railway servants. In this connection we may remark of our own knowledge that no company exercises greater care over the selection and training of its signalmen and in the fullest observance of rules and regulations than the Midland.

The question now arises as to how future similar accidents are to be avoided. As regards that at Ormskirk and the present one, it may be observed that the standard block regulations used by all the companies already provide for safeguarding light engines, &c., standing on the main line. It is there laid down that before any operation with light engines be carried out the signalman shall "block-back," *i.e.*, cause the needle of the block instrument in the signal-box in the rear and of the companion instrument in his own box to indicate "train-on-line," and so not only act as a reminder to both men, but prevent the acceptance of a train. In addition, there is the system of "lock-and-block," which we have fully explained elsewhere in this issue. The question of safeguards against fire in trains after collision is not so easily got rid of. The substitution of electric light for gas is generally suggested, but it is not a recommendation that will meet the whole case. Fires in trains are as likely to be started by live coal ejected from the fire-box by the collision as by gas, and it is on record that an electrically-lighted coach was so destroyed in the Grantham accident, also that the two coaches which first caught fire at Cudworth were so illuminated. Another point, and one that will appeal to the majority of passengers, is that the small inverted incandescent mantles now employed give an admirable light. The companies appreciate, too, that gas is more cheaply produced than electricity, and practically no technical staff is required to look after it. Gas should not then be absolutely condemned until other means have been proved to fail. Cannot there be, for instance, a more generous use of steel in the body of the coach, and the adoption of fire-proof paint, as on the District? Extinguishers and a few fireman's tools might also be supplied to every guard's van. Lastly, it may be asked whether it is not possible to reduce the chances of telescoping? And here it may be remarked that it was only natural, as they came between two engines and a sleeping car that weighed about forty tons, that the two front vehicles of the ill-fated train in question should be crushed. A uniform weight for passenger-carrying vehicles would appear to be another point worthy of attention. But in considering all questions of the kind it must be remembered that with our extraordinarily complete system of signalling collisions are of very rare occurrence, and that the number of persons killed and injured every year in that way is an almost insignificant fraction of the huge number who travel. Taking the last three years the returns show that in 1907 only one passenger in every 70 million carried was killed in all train accidents in the United Kingdom. In the following year not one was killed, and in 1909 only a single person. In that year there were 1264 million chances to one against any particular passenger being killed. The year just ending has a bad record, but it amounts only to twenty-one killed, or probably one in every 70 million or so carried. Of course, the number of injured is greater, but the chances are in the neighbourhood of three million to one against any particular passenger suffering.

GERMANISCHER LLOYD RULES, 1910.

By ARTHUR R. LIDDELL, Charlottenburg.

LIKE the other classification societies, the Germanischer Lloyd has for some years past been reconsidering its rules for the classification of sea-going vessels, and making independent inquiry into the right of existence of many of the survivals from the older times. Embodied in its edition for 1910 are many new ideas, some of them agreeing with those of the English and other societies, but not a few of an original kind.

The growing influence of science on shipbuilding methods, which is gradually making itself felt in better distribution and better turning to advantage of the material, is here to be seen in the alteration of the various parts of the longitudinal structure and in the arrangement and stiffening of the water-tight bulkheads. Alterations in the methods of application of the rules take the direction of the simplification of the numbers for scantlings and of the rearrangement of the nomenclature of the decks.

The awning-decker has now followed the spar-decker to the scrap-heap, and where a draught restriction ensures a lowering of the cargo-carrying limit the reductions in material which thereby become justified are spread over the whole structure, instead of being mostly confined to the upper works as heretofore.

In the determination of the new scantlings the results of experience have everywhere been carefully taken into account, but in very many directions weight has been saved by a more judicious distribution of material without any sacrifice of strength. To such an extent has this been carried that the general structures of vessels now fulfil the strength requirements of the deepest admissible load lines on the weights of the light-scantling vessels of former years. In cases in which long erections are fitted amidships, these also are pressed into the service, so that their decks form the upper chords of the main structures. Not only is the excess material of the main-deck stringers and sheerstrakes transferred to the corresponding parts at the sides of the erections, but particular attention is paid to the connections and supports at the ends of these, so that the upper chord really sweeps down in an unbroken line into the gunwale of the main deck beyond the erection at each end.

The former restrictions of the classification in relation to trading limits are now given up, reductions of scantling being still allowed, however, in coasters and such-like smaller craft which do not run full risks.

The decks, from the topmost one downwards, are now named the main, second, third, &c., and the prevailing prejudice against berths in the "'tween-decks" of passenger vessels may be expected to disappear along with the old names of the 'tween-deck spaces.

As regards the numbers for scantlings, the breadth and depth of the vessel are now made use of for the transverse structure, the measuring of the half girth and the calculation of the number "Q" having been given up. Whereas, on the old system, a compromise between breadth and depth regulated the frames and floors, these groups of members can now be varied, each in accordance with the dimension which most affects it. In the longitudinal number (formerly = Q × L) "Q" has been replaced by (B + H) (breadth + moulded depth), the factor L (length) remaining as before. The rules are arranged for vessels with double bottoms; a vessel in which a double bottom is not fitted is, in the determination of the hold frames, assumed to be 1ft. deeper.

The rival frame and reversed frame, deep frame, and web frame constructions have been reduced to order in the manner that the frames in the lower hold are in general arranged on the deep frame principle, the frame and reversed frame system being maintained for small vessels, and web frames being added for vessels of the largest class, as also for strengthenings in engine and boiler rooms, and at other parts where irregular stresses have to be met. Above the height of the lower hold, up to the main deck, lighter frames are provided for. In a deck-house forming part of the main girder, these are carried up to the erection stringer, but in short poops, forecastles, and similar structures their places are taken by still lighter ones. This stepping of the frames is of especial advantage in a vessel with several decks. In the forehold behind the collision bulkhead space is won by the substitution of a web frame and side stringer construction for the hold beams hitherto fitted here for the prevention of panting. Forward of the bulkhead the old system of bow strengthening is retained and further developed, complete tiers of beams being now required at vertical intervals of about 8ft.

Considerable attention has been paid to the longitudinal structure, the shell in particular being simplified. In vessels with double bottoms the skin is now of the same thickness from the flat plate keel—or garboard strake attached to bar keel—to the sheerstrake.

Additions for extreme proportions of length to depth are made in the not very common case in which the length L is more than twelve times the moulded depth H. The thicknesses of the sheerstrakes and stringers at the upper cord are then to be increased by percentages which grow with the values of L ÷ 12 H.

The changes made in the platings on the decks go still further than those in the shell plating. Below the main deck they are made strong enough to carry the cargo. Of the excesses over this requirement formerly provided for stringers and other strakes on the score of longitudinal strength, a part is removed to the top of the girder, and the rest is dispensed with. Bulkhead liners have given way to supporting knees on each side of the bulkhead in question, this also making for lightness. With regard to double bottoms, the different systems of construction hitherto in use are, in the rising scale of size of vessels, successively applied to the grades to which they are best suited.

For sailing vessels, the hold keelsons have likewise been rearranged. The old-fashioned plate-and-angle rider keelsons obstructed the cargo space, and, whether for longitudinal or for local strength, were of doubtful efficiency. They are now replaced by through-plate or intercostal keelsons projecting less above the floors but attached to the outside plating and arranged at more regular athwartship intervals than heretofore. Here, also, careful investigation has in the different cases resulted either in a gain in strength with little or no addition of weight, or in a saving of weight without loss of efficiency.

The bulkhead question has been carefully studied. The rapid growth in the size of vessels has rendered it imperative that cargo as well as passenger vessels shall have such subdivision as the nature of their services will admit. On the assumption that a length of hold of at least 50ft. must be allowed for general cargo, it is found that four bulkheads are necessary for vessels of 85 m.—about 278ft. 9½in.—in length and one bulkhead more is demanded for each additional 20 m.—65ft. 7½in.—or part thereof. The stiffening of the bulkheads is so dimensioned that under the most severe conditions of water pressure likely to ensue the material, though stressed beyond the elastic limit, will still retain a sufficient reserve against ultimate collapse. Thus, when a vessel has been saved from foundering by a pair of her bulkheads these may have to be renewed when she reaches port. Bulkheads of tanks are, of course, made strong enough to withstand a constant pressure of water. Individual treatment of the bulkheads, though tending to increase the number of channel and other sections that have to be procured from the rolling mills, has here enabled a considerable saving in weight to be effected. The old style bulkheads with vertical and horizontal stiffeners, which still lingered on in cargo steamers, are now discarded, the so-called "strengthened bulkhead" system, which has for years been obligatory in the German passenger service, being now applied to all vessels.

A point to which special attention has throughout the rules been given is the avoidance of superfluous provisions. As an instance of this the breadths of connecting angles of all kinds have been left to be governed by the sizes of the rivets which they are to take.

Subject to the satisfaction of the surveyor in each case, they are determined by the shipyards, which, with less outside interference, are more likely to pay intelligent attention to the requirements for good sound riveting.

The text of the rules is considerably shortened, so that, in spite of the addition of some fresh sections, the book is no thicker than before. To detail all the minor alterations would lead too far, but there is hardly a corner of the structure of a vessel which has not passed under a critical review, resulting in most cases either in increase of efficiency or in saving of weight.

All in all, the Germanischer Lloyd class now stands for vessels that are no heavier than those of other societies, but the expedient of taking material from places where it can be dispensed with, and applying a part of it in others where it can do its full share of work has produced structures that are, if anything, stronger than before. In view of possibly imminent developments in the motive machinery of vessels, shipowners may be expected to welcome any fair means of keeping down expense in their shipping plants, and any reduction in the weight, and therefore in the cost, of vessels they may now have to give out should be of value to them, but promiscuous reduction is apt to spell weakness and frequent bills for repairs.

A section of the rules which has been thoroughly revised and modernised is that on electric intallations. The former provisions have been condensed, and a large mass of fresh matter, embodying the experience gathered in the course of a number of years' working of actual installations on board, has been added.

Provision for the future has been made in a series of new rules for steam pipings of steel and copper. This had become necessary in consequence of the growing tendency towards the use of highly superheated steam in the engine and boiler-room, with accompanying high pressures that were formerly unknown.

A welcome has, moreover, been accorded to the internal combustion engine in the shape of a special section devoted to its general adaptation to marine work. The clauses relating to it are so framed as to hamper design as little as possible, while making for safety and reliability, both of the motors and of their attendants, due attention being given to the fuel tanks, lighting installations and compressed air receptacles, as well as to the motors themselves.

Finality in rules of this kind is in the nature of things impossible, but in the race with progress the rules have probably been brought up to as far advanced a position as is desirable.

COMPENSATED DRAUGHT FOR BOILERS.

In The Engineer of August 12th last, under the title of "Equalised Draught," we commented upon some experiments which had been carried out at the St. Denis Works of the Hotchkiss Company, near Paris, by Mr. S. Heryngfet, to test the value of a novel appliance for regulating the draught of boiler furnaces. The tests showed that with the apparatus mentioned a material increase in evaporation could be obtained, compared with a system of induced draught by steam jets when burning an inferior class of fuel. We concluded our article with the suggestion that the inventor ought to carry out further trials with really good coal

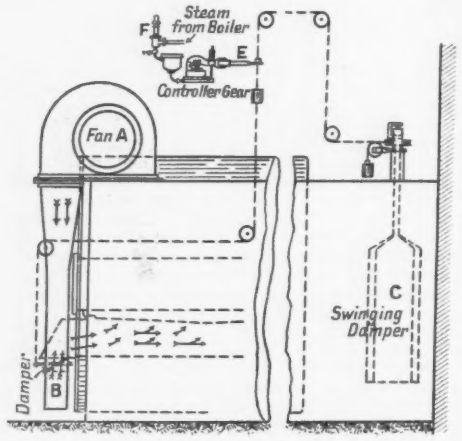


Fig. 1—APPARATUS FITTED TO LANCASHIRE BOILER

capable of getting much more work out of the boilers, as such trials would possess a utility which the experiments referred to lacked.

Since the above article was written the manufacture of the apparatus referred to has been taken up in this country for land boilers by Thwaites Brothers, Limited, Bradford, after tests carried out on the firm's own boilers working under everyday conditions. The apparatus provides means whereby the admission of air to the furnace and the exit of the gases are automatically regulated in such a manner that a uniform pressure—practically that of the atmosphere—is maintained above the fire-bars, irrespective of the rate of combustion, and by which only sufficient air is allowed to pass to ensure something closely approaching the proper chemical combination of the fuel. With such an apparatus, it is claimed, the periodical variations of the temperatures of the gases which result from the admission of cold air over the fuel when the furnace doors are opened are prevented, since the pressure of air in both the furnace and the stokehold is the same. Should the demand on the boiler be increased, an automatic control device comes into action, opening up the air supply and exit dampers simultaneously and sufficiently to ensure the rate of combustion necessary to keep up the steam pressure and *vice versâ*. Although this appliance has not been in use sufficiently long to prove the assertion that the life of a boiler so equipped is prolonged, it is well known by engineers that boilers do suffer by the expansion and contraction stresses caused by variations in the temperature of the furnaces, owing to the infiltration of air through leaky doors or settings, as well as by the inflow of cold air through the fire-doors when open.

The accompanying illustrations show the application of the McLean apparatus to two types of boilers, Fig. 1 being a Lancashire boiler and Fig. 2 a marine boiler of the Scotch

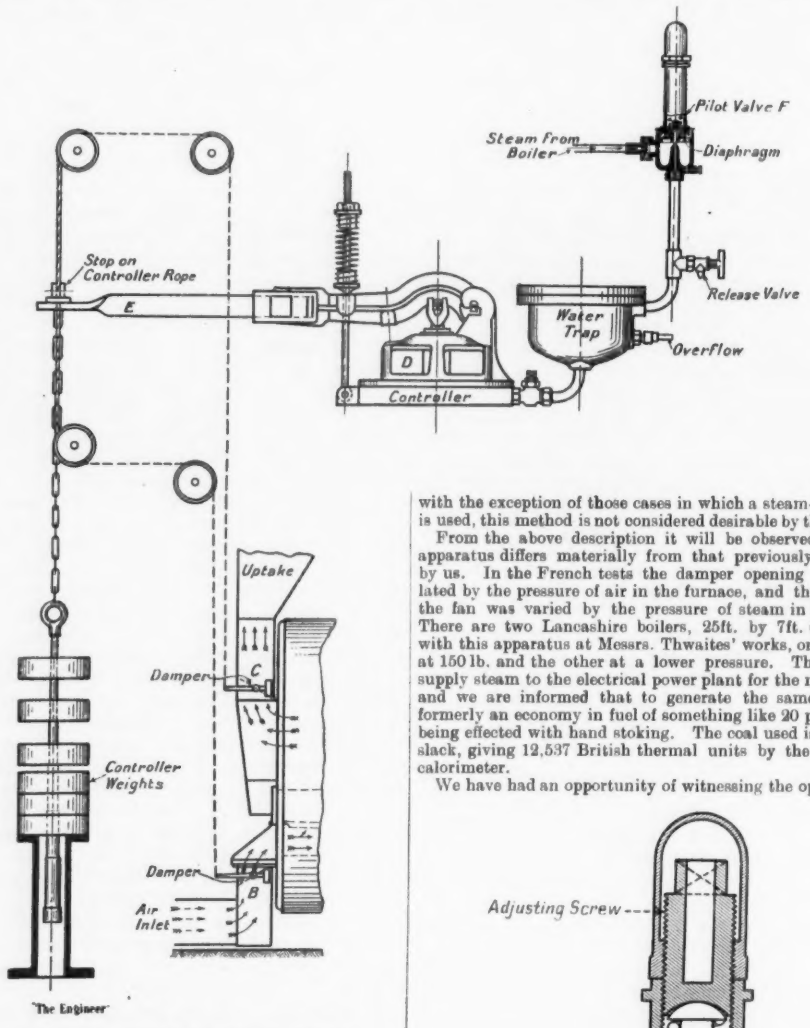


Fig. 2—APPARATUS FITTED TO SCOTCH BOILER

type, while Figs. 3 and 4 show the construction of the controller and pilot valve, on the operation of which the success of the system depends. The apparatus comprises a fan driven by an electric motor or otherwise, which is run at a constant speed, and is capable of supplying a volume of air considerably in excess of that required for the normal rate of combustion. This fan A blows air through ducts B into the closed ashpits of the furnaces, as with the ordinary forced draught, and the flue or flues for the exit of the gases are fitted with a simple form of swinging damper or dampers independently controlled. These dampers C are connected by

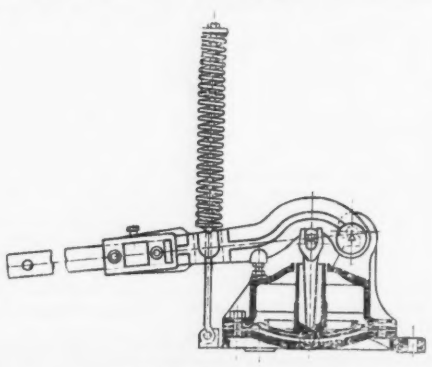


Fig. 3—CONTROLLER

means of levers and wire ropes to the dampers in the air ducts B in such a manner that the action in opening and closing is concurrent and simultaneous. The damper controller D and the pilot valve F may be placed in any convenient position in the boiler-house. The controller depends for its action upon the admission of steam to the lower side of a flexible diaphragm, which is loaded to a predetermined amount by means of balance weights. When the diaphragm is raised the lever E is raised also, and by means of wire ropes attached to it closes more or less the two dampers, thus reducing the draught and diminishing the amount of steam raised. With the fall of the steam pressure the diaphragm falls too, and the dampers are restored to their former position. The controller receives steam through the medium of the pilot valve F. This is simply a spring-loaded needle valve, with a pin and seating of special metal. The needle is raised by means of steam acting upon the diaphragm and allowing the steam to pass to the controller. The valve is very sensitive, and is provided with means to drain off water of condensation. The balance weights on the controller lever are provided to prevent any tendency of the apparatus to hunt, and also serve to bring back the dampers into their full open position when the steam pressure in the boiler has fallen to its lowest limit. It should be noted also that the dampers can be closed by hand and kept closed during the process of cleaning fires. If desired, the speed of the fan—and thus the quantity of air delivered—may be regulated in accordance with the demand for air, but with the exception of those cases in which a steam-driven fan is used, this method is not considered desirable by the makers.

From the above description it will be observed that the apparatus differs materially from that previously described by us. In the French tests the damper opening was regulated by the pressure of air in the furnace, and the speed of the fan was varied by the pressure of steam in the boiler. There are two Lancashire boilers, 25ft. by 7ft. 6in., fitted with this apparatus at Messrs. Thwaites' works, one working at 150 lb. and the other at a lower pressure. These boilers supply steam to the electrical power plant for the machinery, and we are informed that to generate the same power as formerly an economy in fuel of something like 20 per cent. is being effected with hand stoking. The coal used is Silkstone slack, giving 12,537 British thermal units by the Thomson calorimeter.

We have had an opportunity of witnessing the operation of

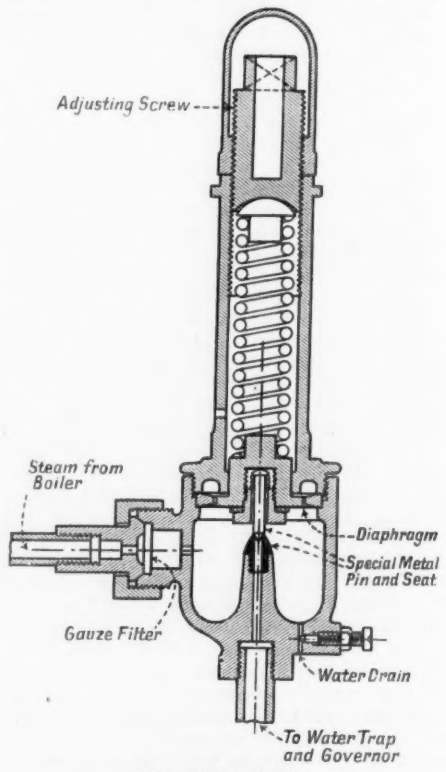


Fig. 4—PILOT VALVE

the apparatus at the makers' works. The automatic controller worked quite satisfactorily, regulating the dampers with great delicacy, according to the load. To show how effectively the draught was equalised, or, in other words, to show that the air pressure in the furnace was equal to that in the stokehold, a piece of paper would remain on the dead plate when the fire-door was opened. The colour of the smoke given out at the chimney was on the whole very pale, but was somewhat darker when the dampers were partially closed. It was, however, at no time such as to be objectionable. The CO_2 in the chimney gases was about 13 per cent., equal to about 1.46 times the requisite volume of air for bituminous coal. The following data referring to a four hours' test carried out at the works on October 20th last have been given to us by the makers:—

Coal consumed	2250 lb.
Coal consumed per square foot grate area	25.3 lb.
Actual evaporation per lb. of coal	9.19
Actual evaporation from and at 212 deg. Fah.	10.002
Overall boiler efficiency	74.1 per cent.
Average CO_2 in flue gases	13.75 per cent.
Coal, British thermal units, about	13,000
Temperature of gases leaving boiler	763 deg. Fah.

A PNEUMATIC COMPRESSION RIVETER.

IN power-riveting the important influence of the pressure exerted and the time during which it is applied is now well understood. Each size of rivet should be closed with a definite pressure which, for boiler work, should work out at about 60,000 lb. per square inch of the area of the rivet head. Further, as the metal of the rivet takes a definite time to flow and does not acquire its full strength until cold it is recognised that after the dies have closed they must be held closed for a few seconds, say four or five, if satisfactory work is to be ensured. The popularity of the hydraulic riveting machine

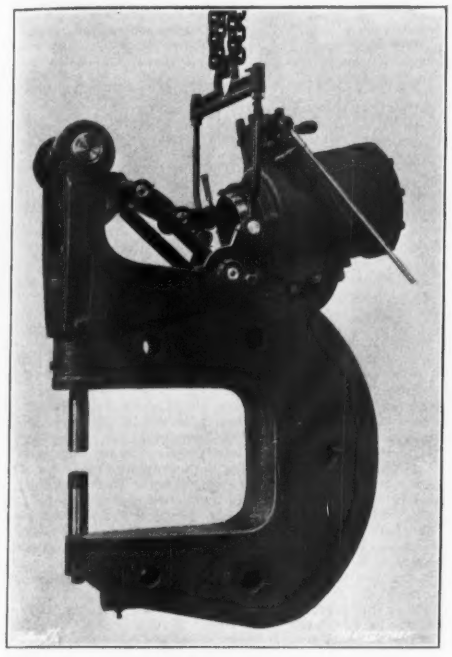


Fig. 1—THE HANNA PNEUMATIC RIVETER

is largely due to the ease with which these results can be obtained. But in the case of the pneumatic riveter employing some simple form of toggle joint there is not the same surety of action. The full pressure is not reached until the toggle links are in line with each other, and the smallest movement of the toggle links when they are just about coming into alignment makes a great difference in the pressure exerted. Hence, in view of the fact that the rivets may vary slightly in length, or the plates in thickness, it is no easy matter to guarantee, when using such a machine, that every rivet will be closed with the same pressure. Indeed, we may say that, in the workman's desire to increase the output of his machine and his consequent disinclination to adjust the stroke of the dies to suit each rivet, it is extremely unlikely that equality of closing pressure is secured with a simple toggle joint type of pneumatic riveter except by accident.

A new type of machine known as the Hanna patented pneumatic riveter, which it is claimed is free from these defects, and which possesses an action closely approximating to that of the direct-acting hydraulic type, is illustrated in the accompanying engravings. Fig. 1 shows a general view of the riveter; Fig. 2 a detailed drawing of it; and in Fig. 3 the arrangement of the toggle joints and levers is shown diagrammatically. Referring to Fig. 3 the first of the sketches shows the relative positions of the links when the piston is about to commence its stroke; the second when the stroke is half completed, and the third when it is finished. It will be seen that from the piston Q a connecting-rod extends to a point C on a lever D. This lever is linked to the frame by a tie E. At the same time the lever D is also linked to the framework by a tie F, and to the ram carrying the upper die by a tie G. The two ties F and G form a toggle, but it is to be noticed that they are pivoted to the lever D at two different points. During the first half of the stroke the toggle links gradually straighten out, and when the piston has travelled half its total distance the links and levers are in the relative positions shown in the second sketch.

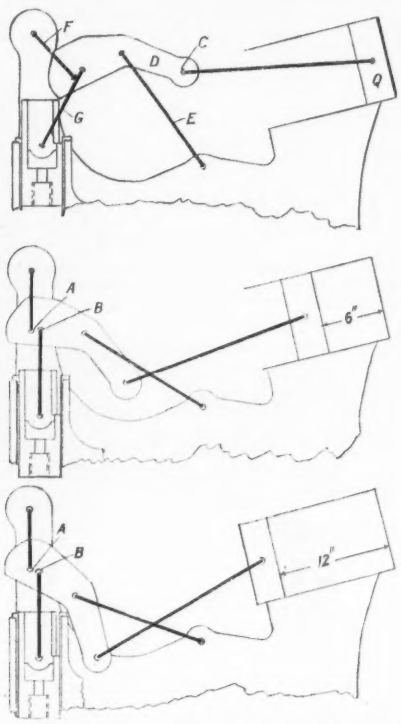


Fig. 3—DIAGRAM OF POSITIONS OF TOGGLE JOINT

The toggle action now ceases, and the further travel of the die is effected by the movement of the lever D until the rivet is closed and the links assume the position shown in the third sketch. It will be noticed that during the second half of the stroke the lever D acts as if fulcrumed at the point A, that is the pivot for the upper toggle link. Again, it will be seen that the point B, only a little distance above A in the second sketch, is only a little distance below it in the third, although the piston travel required to produce this change is just as much as is necessitated to produce the change from the position shown in the first sketch to that shown in the second.

If the kinematics of this system of links be worked out it will be found that during the first half of the piston stroke the die moves quickly, but with a decreasing velocity, until the toggle action of the links F, G is over, and that during the second half of the piston stroke the die is moving slowly and with a constant velocity. It follows, therefore, that during the first half of the piston stroke the die traverses the bigger part of its stroke and exerts a gradually increasing pressure, while during the second half of the piston stroke the die moves only a short distance, and exerts a constant pressure. In an actual example the piston stroke is 12in., and the stroke of the die 4in. During the first 6in. of the piston stroke the die under the action of the toggle links moves through 3¾in. or ⅞ths of its stroke. The remaining 6in. of the piston stroke effect the last ¼in. of the die stroke. It will now be seen that with this type of riveter the closing of the rivets is effected at a constant pressure since it can be arranged that the actual closing of the rivets, even when there is a slight variation in their lengths, shall come within the second half of the piston stroke. By means of a screw for adjusting the upper die it can be arranged that the rivet will be closed when the piston has executed three-quarters of its stroke, that is to say, as far as the die is concerned after it has moved through ¾in. under the maximum constant pressure, and while it is yet ¼in. from the end of its full stroke. Hence, careful adjustment of the die screw for each rivet is unnecessary, and one stroke is sufficient to close the rivet.

In addition to these advantages over the ordinary type of pneumatic riveter it is claimed for the Hanna riveter that it compares favourably with the hydraulic machine. It is pointed out that the Hanna machine requires only 80 lb. to 100 lb. pressure to work it, and that no exhaust or return pipe is required. Hence, it is free from the troubles attendant upon high-pressure hydraulic piping. Again, it is stated that the consumption of power is less with this type of pneumatic riveter than with a hydraulic machine. In a hydraulic riveter full pressure is exerted during the entire stroke, but in the Hanna riveter the pressure exerted during the bigger part of the stroke is light. With a stroke of 4in., and a closing pressure of 45 tons, a hydraulic machine does 45 by 4 = 180 inch-tons of work at each stroke. We understand that in the Hanna machine the total actual pressure in the cylinder under these circumstances would be 5⅔ tons, so that the work done on a 4in. stroke would be 5⅔ by 12 = 69 inch-tons. The makers state that the consumption of free air at 100 lb. per square inch per rivet is 4 to 7 cubic feet for the 30-ton machine; 6 to 10 for the 45-ton; 7½ to 15 for the 60-ton; and 10 to 17 for the 75-ton machine.

Beyond the toggle links and levers the construction of the machine will be readily followed from the engraving shown in Fig. 2, and we need not, therefore, enter into a description of its details. The machine has been largely adopted already in America, where it was originally patented. In this country it is being manufactured under special licence by James Bennie and Sons, Cardonald, Glasgow.

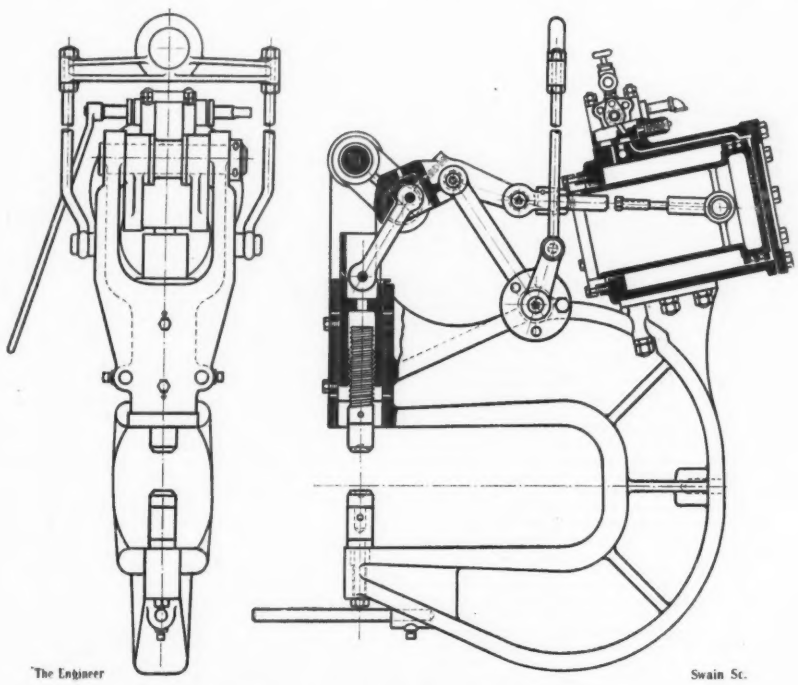


Fig. 2—DETAILS OF THE HANNA RIVETER

THE PRODUCTION OF CASTINGS TO WITHSTAND HIGH PRESSURES.*

By Professor H. C. H. CARPENTER, M.A., Ph.D., Professor of Metallurgy, Victoria University, Manchester, and
Mr. C. A. EDWARDS, M.Sc., Research Fellow and Demonstrator, Victoria University, Manchester.

Introduction.—The object of the investigation was the production of castings of non-ferrous alloys capable of withstanding high pressures, whether hydraulic, steam, or gaseous. The authors were led to undertake this work, in the first instance, owing to the difficulty experienced by Mr. Cook, the instrument maker to the University of Manchester, in obtaining such castings for high-pressure hydraulic pumps. The particular difficulty was not that these castings could not be obtained from the makers, but that they could not be obtained with any degree of regularity. For example, a sound casting might be followed by half a dozen faulty ones before another sound casting was delivered. This fact indicated that the conditions of production were not fully known. An exception must be made in the case of one firm, whose hydraulic castings were almost invariably sound when first cast. These, however, showed so much tendency to "crystallise" that after a year or so they were useless owing to their having become leaky. The authors have devoted the greater part of their time to the study of the production of castings that will stand severe hydraulic pressure, because it is certain that any casting that passes this test will also be capable of holding any steady gaseous pressure that can be reached. They have, however, extended their work to the production of alloys suitable for high-pressure steam fittings.

The following is a *résumé* of the principal materials used in present-day practice:—The British Admiralty specify one of two gun-metals. No. 1 consists of:—Copper, 88 per cent.; tin, 10 per cent.; zinc, 2 per cent.

This must have an ultimate stress of 14 tons per square inch, and an elongation of 7½ per cent. on 2in. It is used for steam valves. No. 2A consists of:—Copper, 86 per cent.; tin, 13 per cent.; zinc, 1 per cent. The tensile test of this is an ultimate stress of 14 tons per square inch and 3½ per cent. elongation on 2in. It is used for work of the highest class, and is demanded for gun-metal gun mountings for naval work. Gun-elevating cylinders are cast in this material. The hydraulic test is 6000 lb. per square inch. It is specified that both these materials must be melted twice. Recently a so-called "high-tension manganese bronze" has been allowed. It has to be cast in dry sand moulds, and its final composition is:—Copper, 56.6 per cent.; zinc, 39.9 per cent.; iron, 1.45 per cent.; manganese, 0.8 per cent.; tin, 1.0 per cent.; aluminium, 0.25 per cent. The specifications of this alloy are:—Hydraulic test, 6000 lb. per square inch; minimum tenacity, 28 tons per square inch; elongation, 15 per cent. on 2in. For hydraulic fittings there is an additional test:—Elastic limit, 15 tons per square inch. In carrying out this test an extension of $\frac{1}{1000}$in. is allowed before the elastic limit is considered to have been reached. Thus the severest test for any alloy required by the Admiralty is the capacity to withstand a hydraulic pressure of 6000 lb., which is less than 3 tons per square inch, and is considerably lower than that contemplated by the authors as the figure to be aimed at.

Among the commercial alloys that have passed through the authors' hands in connection with their investigations the following is of interest in that it is a pure gun-metal containing no zinc and only traces of phosphorus. Copper, 84.87 per cent.; tin, 15.08 per cent.

The alloys in current use thus fall into one of two main classes. Either they are gun-metals with copper and tin as their principal constituents, or they are complex brasses with copper and zinc as their principal constituents. The former usually contain zinc, and may also contain lead and manganese; the latter include iron, manganese, tin, and in some cases aluminium among their minor constituents. "Manganese bronze," as applied to the latter class, is a perfectly misleading term. "Manganese brass" much more nearly represents the facts. The gun-metals 1 and 2A represent metals of only moderate strength and ductility. Upon these the high-tension "manganese bronzes" constitute a considerable advance in both respects. In each case the requirements as to hydraulic test are moderate. In cases where still greater strength is demanded recourse is had to some type of steel. The use of the latter is open to the great objection that whatever kind of steel is used, it rusts in water to a greater or less extent. Consequently there is a great risk attaching to the use of this material in gun-elevating cylinders, and so on. Some admiralties are willing to take the risk, on account of the great difficulty of getting a satisfactory casting in non-ferrous, non-rustable material. The British Admiralty, however, declines to run this risk, and insists

* The Institution of Mechanical Engineers.—(Condensed.)

on the use of gun-metal. It may be well at this stage to enumerate briefly the practical difficulties that have to be overcome, if the production of a casting that will stand the hydraulic test is to be achieved. The simplest way of doing this is to follow the casting of a particular alloy, for example, the 2a gun-metal, from beginning to end, pointing out the difficulties as they occur. The mixture of copper and tin is melted by the aid of fuel such as coke, gas, or oil. During this operation two changes of considerable importance occur:—(1) Some of the charge is oxidised, forming dross or scum which can be minimised if the metals are melted under charcoal. (2) When melted, the alloy dissolvesgas, the amount increasing with the rise of the temperature and the duration of the melting. The composition depends on the fuel used, and on the way in which it is applied. But no alloy melted under practical conditions escapes contamination by gas. When the mixture has reached the proper temperature the zinc is added and the dross removed by stirring and skimming. It is then poured into the sand moulo through a gate which is generally designed to trap any dross and thus prevent it entering the casting proper. Thus, the first point is to ensure that nothing but clean metal enters the sand mould. Any casting containing dross is liable to fail in the hydraulic test. In most cases success can be achieved by the used of fluxes, skim-gates, or risers. The authors, however, have had considerable experience of alloys where none of these "preventatives" was of any use. The alloy has to be cast at a temperature sufficiently above the point at which it begins to freeze to enable it to fill the mould with ease. It then cools to this point and in doing so shrinks. This lessening in volume of the fluid metal as it approaches the freezing point is technically known as "shrinkage," and is sharply distinguished from "contraction," which refers to volume changes in the solid alloy. This shrinkage can always be met by the use of sufficiently large "risers"—that is, feeding heads of fluid metal placed at a convenient position on the casting, and by removing all sharp edges from the mould. If it is not met by some such means, it gives rise to a "pipe" or cavity in that part of the casting which solidifies last.

The solubility of the gas diminishes during this fall of temperature, and it escapes through the liquid metal. At the moment of incipient solidification there is an evolution of gas, the solubility always being less in the solid alloy. Freezing begins, of course, where the metal is in contact with the sand mould, and gradually proceeds inwards. In the case of this particular alloy the temperature interval between incipient and complete freezing is about 150 deg. Cent. During this range the liquid becomes more and more viscous as the proportion of solid crystals increases. This is undoubtedly the most critical period in the cooling stage, because, unless the gas which is set free contrives to escape, it causes the "pinholing" or "sponginess" in the solid casting, which is one of the most frequent sources of failure. These pinholes, due to the trapping of gas originally dissolved in the metal and set free during solidification, are bright and quite free from oxidation tints. They can only be avoided by a proper treatment of the melt in the furnace, and a careful regulation of the temperature at which it is cast.

Another possible source of unsoundness at this stage is the composition of the mould, particularly if it is of green sand. This may give rise to "blow-holes" in the metal, which are distinguished from pinholes by showing oxidation tints. A third source of unsoundness at this stage is unequal rates of cooling in different parts of the casting, leading to the existence of heterogeneity. The areas which freeze first contain relatively less tin, and those which freeze last relatively more tin, than they should. Segregations of tin-rich mixtures occur, and microscopical examination generally reveals minute holes and cracks in their vicinity.

When the alloy has solidified completely, it has still to cool through about 800 deg. Cent. before it reaches the ordinary temperature. Throughout this range it contracts, as a whole, uniformly, except possibly at 500 deg. Cent. Such data as are available do not indicate any marked change in the rate of contraction at this temperature, and for present purposes it can be disregarded. But between 800 deg. and 500 deg. Cent. there are two structural constituents present, namely, α containing about 9 per cent. of tin in copper, and β containing about 22-27 per cent. of tin in copper; while from 500 deg. Cent. to the ordinary temperature they consist of α containing about 9 per cent. of tin in copper, and δ containing about 26-32 per cent. of tin in copper.

It can hardly be doubted that these constituents have different coefficients of contraction, and if such be the case it is difficult to see how the setting up of stresses due to unequal contraction can be entirely avoided. It is here that faults in the metal due to the pattern are so liable to occur. Microscopical examination frequently reveals fractures between the α and δ crystals. Even where fracture does not occur, a condition of stress exists. This reaches a maximum at the innermost parts of a casting. Test pieces cut from there always show mechanical properties inferior to those possessed by the external parts. Thus, even where all the faults that may be caused by metal, mould, and pattern have been successfully avoided, a condition of stress will exist in a casting of gun-metal No. 2A when it has reached the ordinary temperature. This can, no doubt, be alleviated by subsequent heat treatment, but it is questionable whether it can be entirely removed.

Finally, there is the possibility of the deterioration of this alloy due to obscure causes, but probably not unconnected with the existence of stresses such as have been described, and possibly with a change in the constitution of the structural constituents.

The foregoing difficulties may be summarised under three main heads:—(1) Those liable to be caused by the metal or alloy:—(*a*) Dross or scum, due to oxidation; (*b*) piping, due to the shrinkage of the fluid metal; (*c*) pinholes or sponginess due to the trapping of gas set free on solidification among the crystals; (*d*) heterogeneity due to the segregation under certain conditions of particular constituents, and resulting in brittle and sometimes unsound patches in the alloy; (*e*) stresses set up in the solid alloy by the unequal contraction of its structural constituents, sometimes leading to microscopic fractures; (*f*) deterioration due to structural or molecular changes in the alloy with lapse of time, leading to the so-called "crystallisation" of the material, and resultant weakness. (2) Those liable to be caused by the pattern:—(*g*) Stresses set up during cooling by abrupt changes in thickness of section, for example, at the junction of flange and body; (*h*) planes of weakness, if not actual fracture, caused by the crystals growing in a particular direction, for example, in rectangular castings. (3) Those liable to be caused by the mould:—(*i*) Blow-holes due to the mould being too hard, or too damp, or to the sand containing rust or scale. As a result of this analysis of the difficulties surrounding the problem the authors decided upon a line of attack which may be defined in the following general terms:—To start with the simplest case possible, and to work out the conditions for success, bearing in mind the limitations imposed by practice. Having achieved this, to introduce one variable or complication at a time, and to work out the conditions for its success before proceeding to the next, with the object of finally including all these in an ordinary industrial case. This method has been rigidly adhered to throughout the investigation, though there have been stages in the progress of the work when a particular difficulty baffled all attempts to solve it for months at a time. The authors, however, had confidence in their method, and they are convinced that such success as they have achieved is due to a persistent adherence to it.

Experimental arrangements.—The entire work has been done at the University of Manchester. The alloys were cast in the metallurgical department. They were melted in crucibles in an oil-injector furnace, which permitted the handling of ½ cwt. charges. The castings were then machined, and if they appeared to be clean and sound the valve was fitted into them. In the earlier experiments the valve was made of the same alloy as the casting. Inconvenience, however, arose from the fact that sometimes the valve failed before the casting. Accordingly a mild steel valve was used in all the subsequent tests. This valve was coned at one end, and in making the joint it was pulled down so as to "bite" into a flat surface machined in the casting. The arrangement is shown in Fig. 1. The casting was first tested on the pump. The pressure was taken up to four tons. If the casting held this without the least sign of leakage for twenty-four hours, it was considered to have passed the preliminary test. It was then tested on a high-pressure hydraulic pump, designed by Prof. J. E. Petavel, F.R.S., which permitted of the pressure being raised to twenty tons. The following are the requirements of the castings whose production was contemplated:—(1) Mechanical strength, including sufficient rigidity and ductility; (2) homogeneity; (3) soundness; (4) freedom from liability to deterioration; (5) minimum corrodibility in fresh and sea water.

First experiments: The casting of cylinders.—The authors chose as the simplest case possible the casting of a cylinder in a chill mould. By doing this they reduce to a minimum the chance of encountering difficulties caused by the mould and the pattern, and were able to concentrate on the selection of a suitable alloy, and the working out of the conditions of casting it. The mould specially designed for the purpose was made of grey cast iron. The cylinder was 6in. by 2¼in. After cutting off the gate and riser, it was machined to 5¾in. by 2¼in., and was then bored, the bore and thickness of wall each being ¾in. The use of a chill mould not only reduces to a minimum the liability to blow-holes, but also to pin-holes or sponginess. Rapid cooling is one of the chief aids to the escape of gas. By causing molecular contraction it prevents the inclusion of gas bubbles between adjacent crystals, and assists in expelling them through the still liquid interior. Thence they rise through the central portions of the ingot, and are enabled to escape into the air. The difficulties tabulated under 1 (*a*), (*b*), and (*c*) above, would, no doubt, be removed—certainly they would be minimised—if the alloy could be melted and cast in a vacuum. But, so far as practical conditions are concerned, this is a counsel of perfection. The melting and casting have to be done in

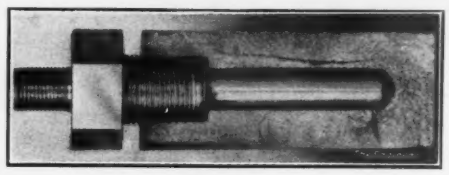


Fig. 1

air. The remaining difficulties 1 (*d*), (*e*), and (*f*) are bound up with the composition of the alloy, and are not due, like (*a*), (*b*), and (*c*), to its contamination by external agents. In the authors, view it is the choice of a suitable material which constitutes the most difficult aspect of the problem. This was accordingly made the first point of attack.

At the outset, experiments were made with a pure gun-metal containing only copper and tin, in the proportions of 85 to 15. Owing to the inappreciable volatility of these metals under the conditions of melting and casting it was easy to make any alloy of this composition, and to repeat it as often as was required. In this respect it presented advantages over the complex gun-metals and still more complex manganese bronzes. Metals of the highest commercial purity were used—electrolytic copper and "Straits" tin, containing 99.98 per cent. of the respective metals. The copper was melted under wood charcoal in a covered crucible. After the addition of tin, sufficient phosphorus, in the form of a copper phosphide containing about 15 per cent. of phosphorus, was added so as to remove oxygen and leave not more than 0.1 per cent. of phosphorus in the cast alloy. After stirring well and skimming, the metal was poured. It was, of course, cast from the bottom. Under these conditions the authors were able repeatedly to produce castings which were perfectly sound and after machining withstood pressures of, on an average, 18 tons before they burst. Previous to fracture there were no signs of leaking. Table I. summarises these results:—

TABLE I.

Alloy No.	Wall thickness. Inches.	Gauge pressure at which fracture occurred. Tons per square inch.	Type of fracture.
1	¾	Valve joint burst at 7 tons	—
2	¾	16	The end flew off.
3	½	14	The cylinder split and the end flew off.
4	¾	18	The cylinder split from end to end.
5	¾	20	Ditto ditto.
6	¾	19½	Ditto ditto.
7	½	18	The end flew off.

A chill casting of this alloy gave the following results in the tensile tests:—Yield stress (not well marked), 17.8 tons per square inch; ultimate stress, 19.0 tons per square inch; elongation on 2in., 3.0 per cent.; reduction of area, 1.6 per cent.

The following details of the tests may be of interest:—Cylinders 4, 5, and 6 fractured exactly in the way that might have been predicted, considering the nature of the stress. They split into two equal parts, an example of one half being shown in Fig. 1. The testing of No. 6 may be instanced. After the preliminary test the hydraulic pressure was taken up to 19½ tons per square inch, when the metal stretched slightly, letting the pressure down to 15 tons. The valve joint was tightened and the pressure taken up, this time to 19 tons, when the same thing happened. After tightening the joint the pressure was taken to 19½ tons, when the cylinder split from end to end. There was no deformation detectible by callipers. The fracture was clean and dry. No 5 was an interesting case, because, instead of the pump testing the casting, the casting tested the pump. At 20 tons pressure the mild steel valve block in the pump expanded and let the pressure out. The screw thread was so deformed that a stronger block had to be made. In the case of cylinders 2, 3, and 7 fracture occurred through the ends of the cylinders being blown off, and the recorded pressures are somewhat lower in the first two cases. The cause of this type of fracture was a sharp angle left by the drill at the bottom of the bore of the cylinder, which, owing to inadvertence, had not been rounded off. But for this fact there is little doubt but that the recorded pressures would have been as great as in cases 4, 5, and 6. So far as chill casts are concerned, therefore, this pure gun-metal alloy, when freshly cast, gave quite satisfactory results, though it showed itself to be a somewhat brittle material.

The next step consisted in casting the same cylinders in sand moulds. These were cast from the bottom, and were supplied with a large riser. Both green and dry sands were used. The castings made in this way were not very satisfactory. Some of them held no pressure at all; others could be taken up to 5-7 tons pressure, but never above this. The conditions of casting were varied in many ways. Attempts were made to cool the castings quickly by embedding blocks of metal in the sand—that is, having the surface of the mould made of sand backed up by metal, and thus producing a mould intermediate between chill and sand, but the castings were no better. This was probably due to the fact that sand is a bad conductor of heat, and as a consequence the cooling was little quicker with the iron embedded in the sand than when the mould consisted of sand alone. The authors are inclined to attribute their difficulties in obtaining sound castings of this alloy in sand to the consequences of the segregation of tin-rich areas, and the trapping of gas bubbles between the crystals during the large freezing interval—about 150 deg. Cent.—of the alloy, which is only slowly passed through. Experiments in this direction were not pushed further because the authors learnt that gun-metals of this composition deteriorate with lapse of time. Quite frequently an initially sound casting becomes leaky after a year or so. The nature of the change is not understood, but it is not very surprising that a change does take place.

Experiments with the aluminium-bronzes were next taken up. From their experience gained in preparing the Eighth Alloys Research Report to this Institution, the authors considered that certain of these might prove to be suitable materials. The following table is taken from page 114 of that report:—

Sand Castings.

Aluminium. Per cent.	Approximate yield stress. Tons per sq. inch.	Ultimate stress. Tons per sq. inch.	Elongation on 2in. Per cent.
7.35	6.6	21.30	71.0
8.12	7.7	24.91	58.0
8.67	9.8	28.1	48.0
9.38	9.7	30.38	36.2
9.90	11.3	31.70	21.7
10.78	14.1	29.52	9.0

These alloys appeared to have the following advantages:—(1) Their freezing interval is so small that there is no segregation, even if they be cast in sand. They are very homogeneous alloys. (2) They possess considerable tenacity and ductility, the former rising and the latter falling as the aluminium is increased. Thus they offered a variety of materials, in the earlier members of which moderate strength combined with great ductility were the principal features, whereas in the latter considerable strength and sufficient ductility were united. It was argued that if a particular alloy were not sufficiently rigid it could be stiffened by a slight addition of aluminium, whereas if it were too hard it could be rendered more ductile by raising the percentage of copper. (3) It is quite easy to prepare an alloy of any of these compositions. (4) Their corrodibility, either by fresh or sea water, is known to be very slight. The first aluminium-bronzes made were cast in the chill mould already described. The first mixtures contained 91 per cent. of copper, and the remainder aluminium. They were prepared by melting the copper in a covered crucible and adding the aluminium to the fluid copper. A considerable amount of dross formed under these conditions. It was removed as far as possible by stirring and skimming. Each mixture was poured at 1125 deg. Cent., which is about 80 deg. Cent. above its freezing point.

With one exception, the castings thus obtained were quite satisfactory. Some of them contained signs of dross, but this appeared to be confined to the surface, and did not affect the soundness of the material. After machining they were tested up to 12-13 tons. At about this pressure the casting stretched slightly, and water was forced through the valve joint. It was possible to raise the pressure to 14-15 tons by tightening up the joint. After this the material stretched again, and the process had to be repeated. At 18 tons none of the four sound castings had fractured. The tests were stopped here. This 9 per cent. aluminium-bronze thus proved itself capable of holding the same high pressures as the 15 per cent. gun-metal, with the difference that it showed greater ductility. Six casts of the same composition were then made in green sand moulds. The metal was poured from the bottom, and a large riser used. Three castings did not even pass the preliminary test. The remaining three appeared satisfactory, and were then tested under higher pressures. The following behaviour of No. 10 may be instanced as typical of these:—The pressure was raised to 10 tons, when the joint opened, releasing the pressure. After tightening it was raised to 13 tons, when it stretched again. By alternately stretching the casting and tightening the valve joint the pressure was ultimately raised to 19 tons. After this, the walls of the cylinder were machined down to ¾in thickness over two-thirds of its length. The cylinder was then tested again. The pressure was taken up by stages to 18 tons without fracture. At this stage the walls had bulged so much that the outside of the cylinder had the appearance of a stressed test piece of the alloy. By the next day the recorded pressure had fallen to 16 tons. The wall thickness was then reduced to ¼in., and the cylinder again tested. It passed through a similar series of tests, and remained unbroken at the end. No doubt if this treatment had been sufficiently prolonged, the cylinder could have been fractured, but this would only have taken place after the hardening produced by the water pressure had raised the yield stress to the same figure as the ultimate stress.

These tests showed that it is possible to cast cylinders of aluminium-bronze both in chill and sand moulds, which are not burst by water pressures of 18 tons per square inch. Their only drawback was that they began stretching at pressures of 10 to 12 tons, the sand castings giving the lower figure, as might have been expected. These results were encouraging, in spite of the fact that, although the sand castings had apparently been produced under the same conditions, only three out of six were sound. Accordingly, it was decided to experiment with a stiffer material by raising the aluminium percentage in the bronze. A bronze containing 9·5 per cent. of aluminium was cast and tested. It stood up to 11 tons pressure before bulging, and then behaved similarly to the 9 per cent. bronze. A 10 per cent. bronze was cast. This was tested up to 12·5 tons before expanding. By alternately tightening the valve joint and exerting pressure, 18 tons were recorded. Next a 10·5 per cent. bronze was cast. This stood up to 14 tons before the joint had to be tightened, after which 18 tons pressure was obtained. The wall thickness was then reduced to ¾in. On re-testing, the cylinder burst at 17 tons pressure. Finally, an 11 per cent. aluminium-bronze was cast. This withstood hydraulic pressure extremely well. The pressure was taken up to 20 tons without any sign of leak. The wall thickness was then reduced to ¾in. On re-testing, 18 tons were recorded before the cylinder burst. The fracture of this material was quite different from that of the 15 per cent. gun-metal used in the earlier experiments. It was confined to a small area, and a decided extension was observed. In this respect it is undoubtedly superior, showing itself to be a tougher alloy.

One of the conclusions reached by the authors in the Eighth Alloys Research Report was that 11 per cent. of aluminium represented the limit of the serviceable bronzes. It appeared of interest to test this conclusion in the present case. A bronze containing 11·5 per cent. of aluminium was cast and tested. It held 15 tons pressure and then burst with no extension. Thus it showed itself clearly inferior to the 11 per cent. bronze. Table II. summarises the results obtained with bronzes cast in green sand, and containing between 9 and 11·5 per cent. of aluminium.

TABLE II.

Aluminium.	Gauge pressure at which the valve-joint began to leak. Tons per sq. in.	Maximum pressure to which the casting was subjected. Tons per sq. in.	Wall thickness of cylinder under test. Inch.
9.0	10	19	¼ cyl. unbroken
9.5	11	15	¾ ,, ,,
10.0	12.5	18	¾ ,, ,,
10.5	14	18	¾ cyl. burst
11.0	no leak	20	¾ ,, ,,
11.5	no leak	15	¾ ,, ,,

The gradual "stiffening" of the castings by increasing the

aluminium is well brought out. Up to 10 per cent. of this element it is practically impossible to burst a sound casting by hydraulic pressure owing to the gradual stretch of the material. The most serviceable bronzes under this test are those containing from 10·5-11 per cent. of aluminium. They are stiff and tough alloys, and break with considerable extension. The 11·5 per cent. bronze is a brittle material, markedly inferior to these. Four more castings of the 11 per cent. bronze were made under the same conditions. One of these failed to pass the preliminary test. Its unsoundness appeared to be caused by dross. The other three held water-pressures up to 19 tons. They were machined down to ⅛in. wall thickness. On re-testing they stood up to 18 tons without leaking and then burst. The investigation had now been advanced to the stage that cylinders of aluminium bronzes could be cast in ordinary green sand moulds, which, except for an occasional failure, were capable of holding hydraulic pressures of 15 to 20 tons. By varying the exact percentage of aluminium, considerable latitude as regards ductility and strength had been obtained. Alloys of suitable composition thus appeared to have been found.

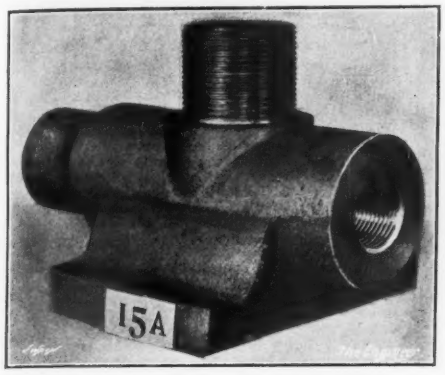


Fig. 2—⅜in. HYDRAULIC VALVE BLOCK

The next step was to produce castings of these bronzes in more complicated forms. The type chosen was a hydraulic valve-block, such as is used in high-pressure hydraulic pumps, and consisting of a lug, a barrel, and base plate. Fig. 2 shows the valve-block after it has been machined for testing. Its dimensions are as follows:—Lug, diameter 2⅝in., height 2in.; barrel, length 8¼in., diameter 2⅝in. at wide end, 2in. at narrow end; base plate, 5⅝in. by 4in. by ⅜in. Two valve-blocks of the 11 per cent. bronze were cast. Neither of them was successful, although the metal was clean and precautions were taken to keep a good head of fluid metal during the solidification. On cutting off the riser it was found that a number of draws were present, distributed radially across the lug. Two casts of the valve block in the 10.5 per cent. bronze were then made. These were also unsound, but the faults appeared to be due not to draws, but to dross, which crept through the skim gate and was deposited on the near side of the barrel. With a view to simplifying the problem, the base plate was removed, and only the barrel and lug cast—Fig. 2. Five such castings were made in the 10.5 bronze. Only one of them stood the high-pressure hydraulic test—15 tons. Even this was not quite free from dross. The others were all more or less contaminated in this way, even though various methods of trapping it were used. Two of the castings showed sponginess in the lug, and one of these showed piping as well. The authors' first attempts were directed to the problem of obtaining clean metal, leaving the piping and sponginess for later work. Experiments were made to clean the fluid metal by the addition of certain deoxidising agents and fluxes, such as magnesium, calcium silicide, sodium carbonate, and borax, but none of these gave satisfactory results. But although these experiments failed to give satisfactory castings, they were productive of valuable information as to how the dross gets into the finished castings. This information may be condensed into the following summary:—The pure aluminium bronzes are very viscous in the liquid state even at the highest temperatures. They pour "thick" and "sluggish." This sluggishness is not directly due to the metal itself, but to a tenacious film of alumina, that is, oxide of aluminium, which invariably covers the surface of the alloy. This can be demonstrated by giving a crucible full of the alloy a rotary movement with a stirrer and noting the surface. It will be seen that the surface film quietly comes to rest whilst the metal immediately below is still moving rapidly. Accordingly it may be concluded—and it is a deduction which the authors' later work supports—that the liquid metal does not offer any unusual resistance to the natural tendency of the dross to rise to the surface. Consequently, as in all cases particular care was taken to have the metal perfectly clean before pouring, the authors were convinced that the dross was in some way formed inside the mould.

By using a large riser on the lug, it was possible to see the metal enter and gradually fill the mould. The metal entering the mould through the well at the bottom of the gate was quite clean. On this metal a skin of alumina formed at once. If, as in the authors' earlier experiments, the metal enters quickly, ripples or waves are formed which break through this skin and expose fresh surfaces of clean metal, which are immediately oxidised. The perpetual recurrence of this process causes the formation of a large amount of dross. This is not carried out of the mould through the riser. The moment it comes in contact with the sides of the mould it sticks. This is why it is present in the castings, and particularly in the upper part. Thus any factor which produces ripples or any other kind of agitation of the metal, causes a much larger surface to be exposed, and so more alumina is formed. The skin of alumina is tenacious and very refractory. Consequently, when two or more ripples overlap, the skin prevents the metal from uniting. This explains why such a large amount of dross forms when aluminium-bronzes are stirred. It follows from the foregoing that the aluminium-bronzes should be poured as quietly as possible, and every care should be taken to prevent the metal being agitated after it has entered the mould. All subsequent casts of these bronzes have been made in accordance with these principles, and all difficulties caused by dross have disappeared. With care and a little practice, castings can be made with regularity that are absolutely free from dross, if the following precautions are adopted:—(1) The metal should be poured very slowly. (2) The gate should be so arranged that the metal enters the mould at the lowest possible point. Broadly speaking, any form of gate will do, but the authors' conclusion is that it is decidedly advantageous to provide a sort of well at the bottom, and use rather a narrow opening. (3) In the case of green sand moulds, wet sand must be guarded against, particularly in the lower parts of the mould where the metal rests on the sand. If a rather close sand is used it is far safer to dry the surface of the lower part of the mould. Under these conditions the metal enters the mould quietly. As it spreads out the skin of alumina is stretched and broken, and fresh alumina is formed until, as in the castings under consideration, the full length of the barrel is occupied. As the metal rises, this skin is not broken but is pushed up until it reaches the upper surface of the mould. After this the metal mounts the riser, pushing the skin until the riser is filled. The final result is a casting with a thin and approximately uniform skin of alumina containing perfectly clean metal inside.

Adopting the above precautions, the authors cast four hydraulic valve blocks, without the base plate, with the 10.5 per cent. bronze and seven with the 10 per cent. bronze. These were, without exception, free from dross. The diameter of the bore in the lug and barrel is ⅜in. Table III. summarises the results of the tests.

TABLE III.

Alloy No.	Aluminium. Per cent.	Gauge pressure at which the valve joint began to leak. Tons per sq. in.	Maximum pressure to which the casting was subjected. Tons per sq. in.	Remarks.
14 A	10.5	14.0	18.0	Sound casting
14 B, C, and D	10.5	—	—	Spongy ,,
14 E..	10.0	—	—	,, ,,
14 F..	10.0	12.0	15.0	Sound ,,
14 G..	10.0	14.0	18.5	,, ,,
14 H	10.0	12.5	15.0	,, ,,
14 I	10.0	13.0	15.0	,, ,,
14 K	10.0	13.5	15.0	,, ,,
14 L	10.0	12.5	15.0	,, ,,

Seven out of the eleven castings were satisfactory. They did not stretch until pressures of from 12 to 14 tons had been reached. All of these were tested up to 15 tons, and two of them up to 18 tons. Owing to the ductility of these bronzes the labour involved in fracturing them under this test would have been excessive. It was not attempted, particularly as the authors had reason for thinking that the pump was likely to fail first. The tests given are quite sufficient to demonstrate the capabilities of the bronzes, and are severer than are likely to be realised in practice. Three of the four bronzes which failed contained—intentionally—small amounts of manganese, the object being to see whether the radial slits that are sometimes found in the riser and lug could be prevented. These castings were all spongy, and two of them were piped in the lug. Manganese really accentuates this difficulty instead of removing it. In this type of casting the best results were obtained with the 10 per cent. bronze, whereas the original cylinders could be satisfactorily cast in the 11 per cent. bronze

The same general principles were then followed in casting the complete valve blocks with base plate. Preliminary experiments were needed to show the most suitable form of gate and well, and a larger riser was used. It was found advantageous to face the mould with a somewhat coarser sand. On account of the base plate exposing a large surface to the bottom of the mould, it was more than ever necessary to dry the latter to ensure that the metal lay quietly on it. In the earlier experiments 10 per cent. bronzes were cast. Some of these exhibited a tendency to sponginess, chiefly in the lug; others were quite sound, and gave satisfactory tests. The later mixtures contained either 9.75 or 9.5 per cent. aluminium. Most of these were satisfactory, and Table IV., based on 15 tests, summarises their properties under the hydraulic test:—

TABLE IV.

Aluminium. Per cent.	Gauge pressure at which valve joint began to leak. Tons per square inch.	Maximum pressure to which the casting was subje ted. Tons per square inch.
10.0	11—12	17
9.75	10—11	15
9.5	9—10	14

The castings obtained in this way were invariably clean, but they were not always sound. This unsoundness usually took the form of pinholes in the lug, but sometimes appeared in the barrel. For a long time the authors were unable to trace this difficulty to its source. Eventually the solution was found by working on the following lines:—Although the castings had been produced as far as possible under similar conditions, one important variable had been present, namely, the duration of the melting of the charge. The furnace worked more quickly at some times than at others. In some cases the charge consisted of pure copper and pure aluminium; in others, of gates and risers of the required composition left over from previous casts. The former took longer to melt. An important consequence follows from this variable, namely, a variability in the amount of gas dissolved in the charge. This quantity will increase with the duration of the melting and the absolute temperature, up to a limit. It will be higher for charges made from pure metals, on account of the greater solubility of gases in these. This difficulty will always be present in making castings under the present practical conditions, namely, by melting in air. It can, however, be minimised, and in the case of the aluminium-bronzes this has been done as follows:—After the melt has been stirred and cleared of dross it should be allowed to remain in the crucible as long as possible before pouring. With the fall of temperature the solubility of the gas diminishes. Corresponding to this there is a liberation of dissolved gas. The lowest temperature at which these alloys can be cast—with slow pouring—is about 50 deg. Cent.—90 deg. Fah.—above the temperature at which the alloy begins to freeze. The latter is about 1040 deg. Cent.—1904 deg. Fah.—so that 1100 deg. Cent.—2012 deg. Fah.—represents in round numbers the lowest temperature at which it is safe to cast. After adopting these conditions, the number of castings showing pinholes or sponginess has been greatly reduced, and while this difficulty still appears occasionally, the authors are now able to produce an average of four good castings out of six.

As a result of the foregoing experiments, coupled with the data on the corrodibility of the aluminium-bronzes given in the Eighth Alloys Report, the authors think they are entitled to claim that most of the requirements of high-pressure castings have been met. It was considered desirable, however, to extend the testing of these bronzes in two directions, namely, with regard to the tensile strength and the deterioration.

The tensile tests were obtained with small test pieces. In view

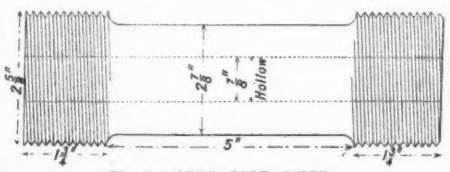


Fig. 3—LARGE TEST PIECE

of the fact that large test pieces give more or less inferior results, cylinders 9in. by 3in. were cast in sand under the same conditions as the valve blocks. These test pieces were thus slightly larger than the barrel of the block. They were machined so as to give a hollow cylinder with a ⅞in. bore, and had the shape shown in Fig. 3. They thus presented considerable similarity to the actual barrel of the valve block. The following results were obtained:—

TABLE V.

Aluminium. Per cent.	Ultimate stress. Tons per square inch.	Elongation on 2in. Per cent.
9.0	25.04	29.6
9.5	28.01	21.0
10.0	26.23	13.0

These values, though not as good as those obtained with the small sand castings of the Eighth Alloys Report are satisfactory, in spite of the fact that each test piece showed considerable sponginess. The specimens had been cast at temperatures varying between 1200 deg. and 1250 deg. Cent. (2192 deg. and 2282 deg. Fah.). In view of the fact that the average temperature was about 100 deg. Cent. (180 deg. Fah.) above that at which the best results with the valve blocks had been obtained, another set of test pieces of the same size was cast at 1100 deg. to 1125 deg. Cent. (2012 deg. to 2058 deg. Fah.). They gave the following results:—

TABLE VI.

Aluminium. Per cent.	Ultimate stress. Tons per square inch.	Elongation on 2in. Per cent.
9.0	18.12	26.0
9.5	21.60	14.5
10.0	20.32	7.0

The fracture of these specimens showed that they were perfectly sound. Notwithstanding this, the tenacity and ductility were inferior to those of the unsound pieces cast at a higher temperature. Accordingly it appears as if some sacrifice of these properties must be made in order to obtain castings entirely free from sponginess or pinholes, so long as they were prepared under conditions which permit of the solution of gases during melting. The values in Table VI. approximate most closely to those of the hydraulic castings themselves, and may be regarded as typical. Though inferior to those in Table V., they are sufficiently good. With regard to deterioration several castings were kept for one or two years, and immediately before the meeting they had been tested. It was found that the results obtained were exactly the same as with new castings.

In the previous tests the aluminium bronzes containing from 9 to 11 per cent. of aluminium have been shown to be capable of holding hydraulic pressures of between 14 and 20 tons. As these are well above the requirements of castings for high gas pressures, the authors did not consider it necessary to initiate any special tests of this kind. There is no doubt that these bronzes possess the requisite qualifications for this purpose, so long as the gas is at the ordinary temperature. The case is, however, different with high-pressure steam, particularly with superheated steam, because prolonged exposure at the temperatures reached may cause a more or less rapid deterioration of the bronze. In this connection Dr. Rosenhain's data obtained with the author's 9.9 per cent. bronze are of interest. They show that there is a steady decrease of tenacity with rise of temperature, which is accompanied by a rise in ductility up to 500 deg. Cent. (932 deg Fah.), although the latter figures are somewhat irregular. The strength is "fairly well" maintained up to 350 deg. Cent. (662 deg. Fah.) after an hour's exposure, but from 400 deg. Cent. (752 deg. Fah.) upwards, it falls rapidly. Although these results are encouraging as far as they go, they do not settle the point whether after, say, a month's exposure to high-pressure steam, the bronzes would have deteriorated. Accordingly, two high-pressure steam valves were cast. As these were small and thin (the wall thickness being 0.25in.), it was deemed safe to cast them with the 10.5 per cent. bronze. They were tested on the hydraulic pump up to 1.5 tons pressure without showing any deformation or leak. One of them was tested for a short time at a steam pressure of 180 lb. per square inch, and held this pressure satisfactorily. Arrangements were then made to test them for a long period with high-pressure steam under "service" conditions. The results of these tests have been quite satisfactory.

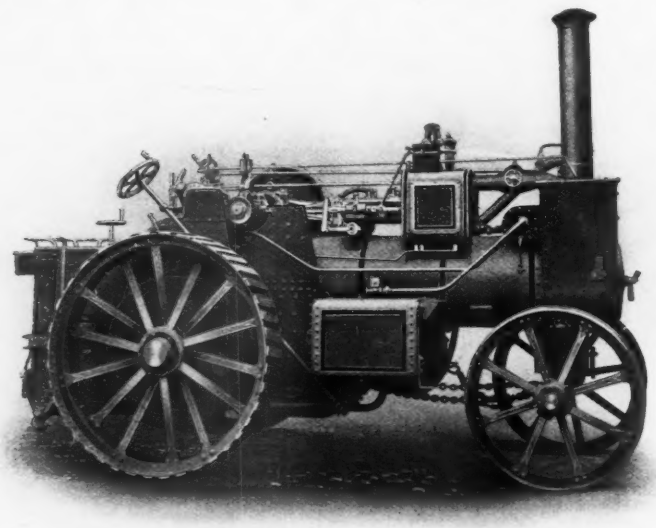
ROYAL INSTITUTION OF GREAT BRITAIN.—The remaining four of the Christmas course of lectures, adapted to a juvenile auditory, on "Sound: Musical and Non-musical," a course of experimental acoustics, by Professor Silvanus P. Thompson, F.R.S., will be held on the following dates:—Tuesday, January 3rd—(III.), "Reception of Sound;" Thursday, January 5th—(IV.), "Combination of Sounds;" Saturday, January 7th—(V.), "Registration of Sounds;" and Tuesday, January 10th—(VI.), "Reproduction of Sound." Lecture hour, 3 o'clock.

ROYAL METEOROLOGICAL SOCIETY.—The monthly meeting of this Society was held on Wednesday evening, the 21st inst., at the Institution of Civil Engineers, Great George-street, Westminster, Mr. H. Mellish, president, in the chair. Capt. C. H. Ley presented his report on the balloon experiments which he had carried out at Blackpool in the early part of the year. The proposal was to employ balanced pilot balloons which, floating in a current with no upward or downward hydrogen velocity, would represent the motion of a particle travelling in that current. Difficulties, however, arose which prevented the scheme being carried out as originally planned. Ultimately a hydrogen balloon or twin system of hydrogen balloon and heavy satellite was so valved as to have a large free lift at first, but continuously to lose gas under the action of a leak until a certain point is reached, when the valve closes, when in accordance with previous adjustment it is nearly in equilibrium. The vertical motion of a fresh wind blowing over a flat country is very slight as a whole, but subject to marked variation on special occasions. In the lowest stratum in the late afternoon there is frequently a large descending current. The apparent effect of a river is to check the wind velocity and cause a downward movement of air over the whole area of the river valley. Capt. C. H. Ley further read a paper on "The Meteorological Significance of Small Wind and Pressure Variations." In this he compared the "yawings" of the wind at Blackpool with the small variations of atmospheric pressure as recorded by the micro-barograph. A paper by Dr. Wilhelm Schmidt on "Atmospheric Waves of Short Period" was also read.

THE LAST VOYAGE OF THE COMET.—A Scotch contemporary recently published an interesting article in which it is attempted to clear up some doubtful points in the history of Henry Bell's Comet by a study of the vessel's cash-book. This book is still in existence, and the entries in it are mostly by the captain, Robert Bain. We learn that the regular crew of the vessel consisted of the captain, a first and second engineer, a fireman, a carpenter, a steward, and Donald M'Dougall, a piper. The vessel latterly ran between Glasgow and Fort William, *viâ* the Crinan Canal, the double journey occupying six days, so that no work was done on Sundays. That as a commercial venture the boat was a success can be inferred from the fact that as much as £70 was sometimes taken for a single trip's traffic receipts. It is on record, however, that Bell's finance required as much engineering as his boat. On December 4th, 1820, the Comet arrived at Fort William for the last time. She was then in a slightly disabled condition, yet, although the master tried to persuade Bell to lay her up for the winter, she set off on the return voyage a few days later. On the 8th of the month the crew had apparently to be boarded for a day near Corran Ferry, while on the 12th and 13th twenty men were engaged on her at suitable states of the tide. On the 14th Oban was reached, and from the fact that four men had to be paid 10s. for pumping the vessel during the night, and that there is an entry of 4s. 6d. against "pump makers," it can be inferred that the boat was now in a bad state of repair. Leaving Oban, however, on the 15th, the Comet began to thread her way through the islands towards Crinan. In a blinding snowstorm late in the same day she ran on to Craignish Point. Until Christmas Day efforts were made to recover the little vessel; but although a few relics, such as the ship's bell and the compass, were saved, she gradually slipped away into deeper water, and was irrecoverably lost. The West Highland boatmen employed at Craignish in the efforts to recover the vessel apparently found relaxation from the strenuous work of salvage by imbibing freely of their native spirit, for the cash-book contains the significant entry:—"December 25th—Whiskey, from 15th to 25th December, to people employed at Craignish, £5 18s. 6d."

REPORT OF JUDGES ON THE R.A.S. TRIALS OF AGRICULTURAL MOTORS.

THE report of the judges in the trials of agricultural motors held at Baldock in August of this year by the Royal Agricultural Society has just been issued, and it is found that the first place has been unhesitatingly given by the judges to the five-ton compound steam engine entered by J. and H. McLaren, of Leeds, which we illustrate below. This engine, as will be seen, is on ordinary traction engine lines, and has cylinders 4½in. and 7½in. diameter with a stroke of 8½in., using steam at a pressure of 200 lb. per square inch. The driving wheels are 5ft. in diameter and 1ft. wide, the steering wheels being 3ft. 6in. diameter and 6in. wide. The heating surface of the boiler is 67 square feet and the grate area 3 square feet, and there is also a superheater, not included in the above. Three speeds are fitted, and the total weight amounts to 4 tons 19 cwt. 3 qrs., the selling price being £530. The rules and nature of the trials and the other competitors were dealt with at some length in our issues of August 12th and 19th, but, judging from the report, the duel between the steam and the internal combustion engine for agricultural purposes therein anticipated was robbed of much of its value owing to various reasons set forth in the report. For instance, the judges state that one of the latter type, "owing to hasty completion and the insufficient time for shop and road trials,



McLAREN'S 5-TON COMPOUND AGRICULTURAL ENGINE

was really doing its experimental tuning up and getting into order in the field trial," while of another engine it is reported that "it showed itself deficient in constructive details, as, for example, in the bearing next the pulley for driving threshing or other machines; this bearing showed a disregard of the power it would have to transmit." Attention is drawn to the fact that the winning machine was capable of drawing the plough at as high a speed as the latter could withstand, which appears to be about 3.3miles per hour. Altogether this machine seems to have proved itself so much the best on the figures of performance all round, such as cost per acre for ploughing, cost per brake horse-power and speed and economy for the road tractor trials, as more than to neutralise the handicap of high initial cost and heavy weight in the opinion of the judges, Messrs. W. Worby Beaumont and R. J. Bayntan Hippisley. It will be seen that the steam engines are in all cases more economical than the internal combustion engines.

A number of tables of results are given in the report, but it will probably be sufficient to reproduce only the actual figures given as the cost per acre for ploughing for each of the seven machines.

Name.	H.P.	Motive power.	Price	Weight.	Cost to plough one acre.	Remarks.
			£	t. c. q.	Shillings.	
J. and H. McLaren, Leeds	40	Steam	530	4 19 3	3.11*	2 cylinders, compound
Mann's Steam Cart and Wagon Co., Leeds	—	,,	400	4 15 0	4.03*	Do.
Wallis and Steevens, Basingstoke	32	,,	410	4 19 0	3.66*	Do.
Ivel Agricultural Motors, Ltd., London						
single gear	18	Paraffin	275	1 13 0	4.47*	2 horizontal cylinders
Do. double gear	18	,,	310		4.47*	Do.
Saunderson and Gifkins, Bedford	45	,,	450	4 15 0	7.45*	4 vertical cylinders
Do.	25	,,	360	3 5 0	7.02*	Do.

* These figures include fuel, lubricating oil, motor drivers', ploughmen's, and boys' wages, and water, but do not include capital charges maintenance, or depreciation. They are arrived at by taking coal at 30s. per ton, paraffin at 8½d. per gallon, petrol for starting up at 1s. 3d. per gallon, water at 1s. per 100 gallons, and drivers' wages at 35s. per week.

In conclusion, the judges state that "they are unable to recognise in any of the machines entered for the trial the agricultural motor which is hoped for as the ideal general-purpose tractor and engine for farm purposes." They are unable to specify what that motor should be, but suggest that "it should not be too heavy, but should be capable of so much of the tractor work as may enable the farmer to dispense with the hiring of the traction engine and of performing enough of the field work and other work for which an engine is required on a farm."

THE Receiver of Wrecks at Aberystwyth has been informed of an immense quantity of wreckage thrown up on the coast between Towyn and Aberayron. Huge spars and combings of a large sailing vessel have come ashore at Borth, together with a lifebuoy bearing the name "s.s. Saba, London." Casks of petroleum, pitwood, shifting boards, and a large quantity of tallow have also been washed ashore south of Aberystwyth. Pieces of cabin doors have also been picked up, but there is nothing amongst the wreckage to connect it with the three Brixham trawlers which are reported missing.

LETTERS TO THE EDITOR.

(We do not hold ourselves responsible for the opinions of our correspondents.)

THE TRADER-ENGINEER.

SIR,—The address of Mr. Railing before the Institution of Electrical Engineers at Birmingham recently gives much food for thought. It opens out a subject that is not often mentioned at meetings of scientific societies. This is a pity, because after all most of us are in the business for our bread and butter.

The address should be studied by every young engineer, and some of the older ones who are still in the scrimmage would be all the better if they took a few of the lessons to heart.

Our geographical position was a great help to early political consolidation, and as a result, whilst other European countries were engaged in internal turmoil, we were quietly developing our trade. Now, on account of ease of transport, the telegraphic and postal facilities, &c., and the opening out of the East and Africa and other parts of the world, our geographical advantage has been greatly lessened. In the meantime, other countries have settled their differences, and also consolidated, so that from being able to supply themselves they have come rapidly to the front as world traders like ourselves.

In this they are being helped by their Governments in various ways. For example, where the railways are national, as in Germany, by specially low railway rates, or, as in America, by the direct employment of their consular officers as aids to trade. But most of all are they being helped by their "trader-engineers," to use the appropriate name coined by Mr. Railing.

When the writer was in Australia, it was disheartening to see good British engineering firms appointing, as their agents, merchants in crockery ware, food stuffs, wool, &c., and especially so because at the same time the Germans and American firms were placing their interests in the hands of expert trader-engineers.

In a small way the writer used to try and make known the names of the smaller specialist—and then unrepresented—English firms by distributing their catalogues to the engineering students at the University. But, alas, this was stopped when the New South Wales Government put a duty of 3d. a pound on such literature. Catalogues for the Colonies and abroad should be specially printed on thin paper and lightly bound, otherwise they may not be claimed from the customs when there is so much duty to pay.

British firms have been slow to recognise the importance of sending out—or employing those already there—who are expert trader-engineers. The specialist firms—that is to say, the smaller firms making a few lines really well—have either left the field entirely alone, or else been content to appoint some shipping agent who has been importing crockery, or corsets, hardware, or some business at the opposite pole to engineering.

When such appointments are made, it annoys the engineers who are on the spot, for the genuine engineer in Australia is as keen about the dignity of his profession as any Great George-street man. When he finds J. S. and Co., shippers, who have built up a reputation as importers of sheep dip compounds, suddenly blossoming out as electrical engineers—well, it is irritating, to say the least.

The trader-engineer who is wanted to open up fresh ground in the Colonies or abroad should have received an engineering training, plus some experience in the estimating office and sales side. He should be of good address, athletic, tactful, resourceful, and socially inclined. Equally at home in discussing an engineering paper before the local society, or in talking over financial matters with the manager of a shipping house or a bank. He should not only be able to follow up and clinch a Government or municipal contract where the money is safe, but he must have some amount of dash. For example, he must have the "nous" to spot and help those of his long credit customers who he thinks will succeed. Many a firm's success has been in part due to the fact that it helped along some battler in his early days. He should be able to sell without seeming to be unduly pushful, and he should know the little tricks which go to expedite the closing of a deal. Also last, but not least, he must understand what is meant by "publicity effort," and be ever ready to take advantage of the undoubted facilities for pushing trade that the Press can give.

There is room in the Colonies and abroad for the right men to represent British firms and open out business. Under our present system of training the finding of the right men is more or less of an accident. The writer believes with Mr. Railing that trader-engineers can be, and should be, systematically and carefully trained for the position. The engineering training should come first, and then the right kind and right amount of commercial "nous" and acquaintance with financial matters be grafted on to it.

The commercial man pure and simple is all very well for trading currants and crockery or cocoa-nut oil, or perhaps putting through a doubtful company's promoting deal. We've had enough of that type in engineering. He should be "downed and outed."

Kent, December 14th. E. KILBURN SCOTT.

CORROSION OF IRON.

SIR,—Perhaps the experience of a brewer respecting the corrosion of iron may be of interest, though I make no pretence to any elucidation of the mystery. But one or two observed facts may be stated.

(1) Iron tanks in which "spent" hops have been boiled for two or three hours are rendered immune to rust, owing to the tannic acid of the hops combining with the iron and forming an impermeable coating of ferric tannate.

(2) Iron spanners and fittings used in connection with pumps situated near the boiling coppers and constantly damp with steam, &c., seem to be also more or less immune, though whether this be due to constant handling or to cleaning is not very clear.

(3) Steel joists situated in the fermenting rooms where CO_2 is constantly present are certainly more prone to corrosion than those in other parts of a brewery, which fact seems to support the theory that carbonic acid has some connection with the trouble.

I fear the tannic acid treatment would be quite inapplicable to large steel structures unless some system could be devised of projecting the acid on to the steel with high-pressure steam. But even, if effectual, the expense would probably be prohibitive, as tannic acid is not a cheap commodity.

I cannot help thinking, however, that research might profitably be directed to finding out why there are so many instances of steel and iron articles and fittings not undergoing corrosion where they might reasonably be expected to do so. Numerous instances of this must be in the cognisance of every engineer.

Reigate, December 15th. X.

GREAT WESTERN BROAD-GAUGE ENGINES.

SIR,—It would be of much interest if your correspondent would tell us something to explain the bad performance of the big Gooch engines. They were quite competent to exert a net draw-bar pull of 750 indicated horse-power. The coaches they hauled could not have weighed more than about 20 tons, and yet five of them seems to have been a maximum load. Such a train ought to have been no more than enough to steady them.

I myself have had some foot-plate experience with Mr. Deans' engines altered from the broad to the narrow gauge. Their boilers were not so powerful as those of the "Iron Duke" class, but they had not the least difficulty in keeping time from London to Swindon, or Swindon to London, with seven and even eight coaches, weighing 25 to 28 tons each.

Was the resistance of the broad greater than that of the narrow gauge? That it might be so on sharp curves I can understand, but there are no curves of moment between Paddington and Swindon.

Did the engines fail from lack of adhesion?

December 28th. SYRINX.

LAUNCHES AND TRIAL TRIPS.

ESCRICK, steel screw steamer; built by Wm. Gray and Co., Limited; to the order of the London and Northern Steamship Company, Limited; dimensions, 395ft. by 53ft. by 25ft. 5in.; engines, triple-expansion, 25in., 41in., 68in., pressure 180lb.; constructed by the builders; trial trip, November 30th.

FRANCISCO, screw steamer; built by the Northumberland Shipbuilding Company, Limited; to the order of Thos. Wilson, Sons and Co., Limited, of Hull; dimensions, 425ft. long; trial trip, December 9th.

LEVENFOOL, steel screw steamer; built by Ropner and Sons, Limited; dimensions, 389ft. 3in. by 57ft. 6in. by 28ft. 6in.; engines, triple-expansion, pressure 180lb.; constructed by Blair and Co.; launch, December 16th.

THORNABY, steel screw steamer; built by Craig, Taylor and Co., Limited; to the order of Henry Clapham and Co.; dimensions, 392ft. by 52ft. by 29ft. 6in.; engines, triple-expansion, 25½in., 43in., 70in. by 45in. stroke, pressure 180lb.; constructed by MacColl and Pollock, Limited; launch, December 16th.

MALOJA, twin-screw steamer; built by Harland and Wolff, Limited; to the order of the Peninsular and Oriental Steam Navigation Company; dimensions, 569ft. by 62ft. 9in. beam; engines, quadruple-expansion; constructed by the builders; launch, December 17th.

CONTRACTS.—Among orders recently booked by Andrew Barclay, Sons and Co., Limited, Caledonia Works, Kilmarnock, are eight locomotives, three of which are for the Port of London Authority.

ASSOCIATION OF MINING ELECTRICAL ENGINEERS.—The next meeting will be on Tuesday, January 17th (not the 4th), at 8 p.m., in the room of the Junior Institution of Engineers, 39, Victoria-street, Westminster. The paper on "Electricity in New South Wales Collieries" will be discussed, and it is expected that several prominent Australians will take part.

ELLIOTT CRESSON GOLD MEDALS.—Seven Elliott medals were awarded in the early part of the month, no less than four of the recipients being British born. They were:—Dr. John A Brashear, of Pittsburg; John Fritz, of Bethlehem, Pa.; Dr. Harvey W. Wiley; Edward Weston, of Newark, N.J.; Sir J. J. Thomson, Professor Ernest Rutherford, and Sir Robert Hadfield. The last three are, of course, known to all our readers, but it will not be so generally recognised in this country that Mr. Edward Weston, whose name is so familiarly connected with electrical measurements, was born and received his education in this country before going to the United States in 1870. The Elliott Cresson Trust was founded in 1857 for the encouragement of invention in the mechanical arts. It has been very ably administered by the Franklin Institute, and the medals awarded are regarded in the United States as being the "Blue Ribbons" of Science.

CHEMICAL ENGINEERING.—The governors of the Imperial College of Science and Technology, at South Kensington, have made another move in the direction of providing the most advanced instruction in science—especially in relation to industry. They point out that for some time past it has become increasingly evident that the training afforded in existing institutions in this country, either in chemistry or in engineering, has not resulted in the provision of individuals adequately trained for the design specification and erection of plant to be used in chemical manufactures. The chemist has an insufficient knowledge of engineering, and the engineer is not sufficiently well versed in chemical data. A course of instruction designed to meet these difficulties is accordingly to be given at the Imperial College. The course will include lectures, laboratory work and drawing, and will last for about twenty weeks, two days per week being wholly taken up by it. It is to commence at 10 a.m. on Tuesday, 17th January next, in the Chemistry Department of the Royal College of Science, Imperial Institute road, S.W.

THE IRON, COAL, AND GENERAL TRADES OF BIRMINGHAM, WOLVERHAMPTON, AND OTHER DISTRICTS.

(From our own Correspondent.)

Closing Up the Year.

THE works have not yet got into operation again after the holidays, but next week the iron mills and forges will be running with their customary speed in the majority of cases. Exceptions there will be where the condition of the order books at the offices, or the necessity of carrying out prolonged repairs to plant, dictate such a course, but these exceptions will not largely affect the district as a whole. The number of cases in which the holidays will be prolonged through lack of business is, happily, not considerable. The attendance on the Ironmasters' Exchange in Birmingham to-day (Thursday) was, however, quite of a holiday character, and the contracts put through were, it must be reported, proportionate alike as to iron and steel.

Iron Prospects for 1911.

Confidence exists regarding prospects for 1911. This is very satisfactory and engenders gratification on all sides. The pig iron trade may be almost said to be assured of a good year already, so capable is the outlook in this branch. What is most needed is increased definiteness as to manufactured iron. Belgian competition still looms large on the horizon of the common and second-class bar makers, and the low prices which will probably rule in this department will, there is some reason to fear, depress other of the rolled iron departments, such as stripe, hoops, &c. Sheets, however, both plain and galvanised, and all descriptions of plain sheets, whether for working up, stamping, or galvanising and corrugating purposes, are likely to see a repetition of the good times of 1910. In rolled steel too the outlook is pleasant, but the semi-product trade will still have to contend with German, Belgian, and even American imports in the shape of bars, billets, &c., which are almost certain to prevent home prices from reaching a much higher level than now.

Iron and Steel Prices.

Prices of iron and steel weaker; raw or finished are this week nominal in the absence of any flow of business, and may be regarded as unaltered upon those given in last week's report.

Railway Rolling Stock Building.

Birmingham railway rolling stock firms will not start 1911 with any considerable volume of work, but it is believed that there are better times ahead for this local industry. The amount of work available at present is restricted alike on home and export account, and consequently home and international competition is very keen. Employment, however, remains fairly steady, and things locally have been made better by the recent distribution to the Metropolitan Amalgamated Railway Carriage and Wagon Company, Birmingham, of the contract for 311 freight wagons which the Central Corboda Railway Company lately gave out.

Coalmining Extensions.

The extensions in the Warwickshire coalfields continue, and are assuming very important shape. The borings of the Warwickshire Coal Company, close to Coventry, have gone as deep as 2400ft., and the quality of the coal throughout the company's area of 1000 acres is believed to be even better than that of pits long worked. In the near future the borings will be followed by sinkings. In a south-easterly direction from the city, on the Earl of Craven's estate at Binley, Merry and Cunninghame, Limited, the well-known ironmasters, of Glasgow, have of late sunk two pits, and the erection of a new colliery village which is going on is an earnest of large mining operations before long. Coventry seems likely to become some day a centre of the Warwickshire coalfield.

Railway Development.

Three years ago the London and North-Western Railway Company obtained an Act for the making of a branch mineral line around the north-east of Coventry to carry coal from Bedworth and south to Rugby and London without the traffic passing, as now, through Coventry Station. Part of the ground has now been cleared, and early next year the construction of the new line is to be undertaken. The new line leaves the main track a mile south of Coventry Station, then turns north, and joins the Nuneaton branch railway at a spot called Bedlam Gates. The distance traversed is 3½ miles, and there will be four or five overhead bridges. From Bedlam Gates, when certain local collieries, which have not yet been sunk, but on which the borings have been completed, are by and by working, it is intended to throw out a branch line to the west, and Bedlam Gates must then become the focus of a heavy mineral traffic to the metropolis.

NOTES FROM LANCASHIRE.

(From our own Correspondents.)

MANCHESTER, Thursday.

Manchester Exchange.

OWING to the holidays there has been practically no business done in iron and coal. Last week's quotations are repeated.

Sizing Cotton Yarns.

A lecture of considerable interest to those connected with the cotton industry was read a few nights ago in Manchester before the School of Technology Textile Society by Mr. J. Sagar on "The Atmospheric Influence on Size and the Sizing of Cotton Yarns." The author said that although millowners were disposed to adopt all the latest devices in the spinning department, in the preparation and weaving departments, much more needed to be done. He spoke of the bad ventilation of sizing rooms often met with, and said that a temperature of 80 deg. was the most suitable for expelling steam from the room. If there was an atmosphere in which the hygrometer indicated 80 deg. on the dry and 60 deg. on the wet bulb, it was improbable that any bacteria would develop in reasonable time whilst the sized warp was in the weaving shed, irrespective of the administration of chloride of zinc, caustic soda, or any other antiseptics in the size, on condition that certain adjustments in the sizing machine and sizing room were complied with. The author then went on to describe the ideal sizing room, in which he condemned the use of stone and concrete floors by reason of their cold and moisture attracting qualities. The extraction of steam came in for consideration, and the author mentioned emphatically that it was a mistake to allow sized yarn to go on the beam cold. No injurious effects were experienced if the temperature of the yarns was kept between 70 and 80 deg.

New Manchester Library and Art Gallery.

The much discussed new library scheme for the old infirmary site has been advanced a stage further by the committee authorising the publication of advertisements for competitive designs. The competition will be open to all architects, and from the designs sent in ten will be selected, to the author of each of which £100 will be given. The author of the design finally chosen will be authorised to carry out the work on the usual terms.

Colliery Explosion.

Although some of the witnesses at the inquest on the unfortunate victims of the terrible explosion at the Pretoria Collieries appear to infer that the Yard Pit was of a fiery nature, the pit was generally considered to be as safe as any in the country, and the cause of the disaster is a mystery. The Pretoria Collieries consist of two shafts situated about 100 yards apart and giving access to four or five different coal levels. The seam nearest the surface is the Trencherbone, and below is the Yard. Both these seams are reached by the same shaft, while the other shaft gives access to the "Three-quarters" and to the Arley seams, the latter being the lowest of all. Fresh air is admitted down the latter shaft, circulates through all the workings and is extracted again at the first-mentioned shaft. The explosion seems to have originated in the Yard seam and spread to the "Three-quarters" seam, and it was in these seams where the loss of life has occurred. Strange as it may seem, if the system of ventilation had not be so thorough the loss of life would possibly have been confined to a large extent, if not entirely, to the seam where the explosion occurred. Shot firing is not allowed, hydraulic pressure being use instead to bring down the coal. The disaster followed closely upon the publication of a colliery warning published on Monday in the papers circulating in the mining districts. This warning called the attention of the workers to possible escapes of gas from the coal seams, associated with earth movements arising from the surges of atmospheric pressure passing over the country.

Fire at a Shipbuilding Yard.

Considerable damage was done by a fire which occurred at the shipyard of A. Rutherford and Co., Birkenhead, last week. It is estimated that the damage caused will amount to £20,000. Three steam launches, ready for delivery, have been destroyed.

Manchester Ship Canal.

The Ship Canal Company has a Bill to come before the next session of Parliament which provides for the construction of a pier or jetty in the estuary of the Mersey at Hooton, on the seaward side of the eastern entrance lock to the canal at Eastham; for the construction of a railway at Eccles between the Latchford Locks and Eccles Wharf. It is proposed that the pier shall be included in the Port of Manchester, together with the adjacent portion of the Mersey. The Bill is further intended to enable the Canal Company to grant leases of land for 999 years, instead of 99 as at present.

A New Motor Car Firm.

I understand that Crossley Brothers, Limited, are about to transfer their motor car business, including the admirably arranged motor works at Gorton, to a new company called Crossley Motors, Limited. The amalgamation of the manufacturing and selling interests is secured by Crossley Brothers, Limited, acquiring the share interest in Charles Jarrott and Letts Limited.

BARROW-IN-FURNESS, Thursday.

The condition of the hematite pig iron trade hereabouts is one of promise. For some weeks now a cloud has been hanging over trade generally, but the position has improved very considerably and gets better every day. When the holidays are over and business is resumed, it will be with a better feeling, for there is every reason to believe that a spell of much brisker trade is at hand. The requirements of users of iron are fuller not only on local but on general account. At present many good orders are held, and the furnaces in blast are turning out a large tonnage of iron, and at the same time additional furnaces are in readiness to be put into operation. Prices are rather higher, with makers quoting 67s. 6d. per ton net f.o.b. for parcels of mixed numbers of Bessemer iron. For special qualities of iron there is a good regular demand, and the current quotation is up to 70s. per ton, and in some cases higher than that. There has been nothing done in warrants this week, which are quoted at about 65s. 6d. per ton net cash. Warrant stores stand unchanged at 34,073 tons.

Iron Ore.

For iron ore the demand is well maintained both as regards local consumers and smelters in Scotland and other places. Throughout the district there is activity at the pits, but more especially are the Hodbarrow Mines busy, from which the highest class ores are obtained. At Lindal Moor, Roanhead, and Park a good output of ore is being maintained. Prices are firm, with good average qualities at 12s. to 16s. per ton, and the best ores run up to 21s. per ton. The demand for Spanish ore continues to be in good request. The current rate is 12s. to 21s. per ton delivered. Two large cargoes arrived in Barrow last week of this class of ore. There was also landed in Barrow 7000 tons of manganese ore from Bombay and some 500 tons of Irish ore arrived from Glenarm.

Steel

The steel trade presents no new features. At the Barrow works orders are held for rails, and when the holidays are over the mills will be regularly employed. Of late some fair shipments have been made of steel rails, which have been sent from Barrow in coasting steamers to the Mersey, there to form part of huge cargoes for overseas. The general demand for rails is steady without being particularly brisk. Heavy sections are quoted at £5 7s. 6d. to £5 10s. per ton. Tin-bars, billets, &c., represent fair businesses. The demand for steel shipbuilding material has improved all round.

Shipbuilding and Engineering.

These trades are observing the Christmas holidays, but commence again on Tuesday next with a full programme of work in every department, and there is a busy time ahead. Some of the departments are working all this week. With the resumption of work next week every endeavour will be made to make up for lost time in view of the time limit in contracts.

Fuel.

There is a steady demand for coal and coke, and prices are not in any way changed. Good steam coal from Lancashire or Yorkshire pits runs from 12s. 6d. to 16s. per ton delivered, and East Coast coke is quoted at 21s. 9d. per ton delivered.

THE SHEFFIELD DISTRICT.

(From our own Correspondent.)

General Conditions.

THE present week has witnessed the temporary cessation of operations in most departments in the steel trades for stock-taking and for the effecting of repairs and renewals of plant. Interest now centres on the prospects before trade in the new year, and all round there is a most hopeful feeling. The year has closed with better trade conditions in Sheffield than last year, and, although the present bank-rate is much against large enterprise, there is a large volume of trade in the country. The great South American countries are resuming their purchases of manufactured material. India has yet to buy, and the demands of Canada and Africa continue their great recovery. With the shipbuilding lock-out settled, there is every prospect of a much improved demand for steel from that quarter. It is also thought, too, that the home railway companies are now preparing for a more normal expenditure on rolling stock, in view of the definite growth in traffics and the fact that the limit has been reached in the economies possible from the various working arrangements. The Government's shipbuilding programme is, moreover, not yet completed, and a continued stimulus is expected to be given to Sheffield's steel trade in the coming year by the demand for armament material. The one unsatisfactory feature is furnished by the finished iron trade. A lull has again set in, the indications a short time ago that demand was definitely recovering having proved to be only a "flash in the pan," and the eve of the holidays found the bar mills very ill supplied with specifications, while manufacturers have no great weight of orders on their books, and so far as can be seen at present, the hand-to-mouth buying which has obtained throughout the year bids fair to be continued.

Coal, Iron, and Steel Trades.

With business at a standstill there has been no quotable alteration in values, and we repeat our quotations of last week. Coal: Best South Yorkshire hards, 8s. 6d. to 8s. 9d.; best washed smalls, 5s. 6d. to 6s.; best hard slacks, 5s. 6d. to 5s. 9d.; seconds, 3s. 9d. to 4s. 3d.; coke, 12s. 6d. to 13s. for best washed, and 11s. to 12s. for unwashed. Pig iron:—Quotations: Best brands of hematite remain at 79s. to 80s. West Coast, and 74s. to 75s. East Coast. Other quotations are:—Lincolnshire, No. 3 foundry, 50s. 6d.; ditto, No. 4 foundry, No. 4 forge, mottled, and white, 49s. 6d.; basic, 52s.; Derbyshire, No. 3 foundry, 50s. to 52s.; ditto, No. 4 forge, 48s. 6d. to 49s, all per ton net delivered Sheffield or Rotherham.

NORTH OF ENGLAND.

(From our own Correspondent.)

Cleveland Pig Iron.

NATURALLY this has been a dull week in the pig iron market, but that does not lead to any weakness in prices, for it was only what was to be expected, and the prospects are very favourable for 1911. There is, however, one drawback, and that is the enormous stock of Cleveland pig iron which is lodged in Connal's public stores—it was 527,652 tons on Wednesday, 20,595 tons having been added this month, and about 137,000 tons this year. The chances of getting it off the market are not anything like so good as in 1906 and 1907, for the two countries which greatly assisted in clearing off the 750,000 tons held in Cleveland in the early part of 1906—Germany and the United States—are producing considerably more iron than satisfies their customers, and now, instead of taking Cleveland iron, they are competing with the Cleveland ironmasters in neutral markets. The other day it was reported that 10,000 tons of Alabama pig iron had been sold to Italy, and more was on offer at cheap rates. That had the effect of depressing the Cleveland warrant market, for Italy has been one of Cleveland's best markets for pig iron. In 1907 Germany took 488,639 tons of pig iron from the Cleveland district, and North America 274,406 tons, but this year Germany has required less than a third of the above-named quantity, and the United States only a small tonnage. It will be necessary to find new markets for the pig iron if the production is to be kept up, and it is not easy to see where they can be found. Nevertheless, traders take a very sanguine view of next year's prospects, and makers ask substantially higher prices for delivery forward than rule for early delivery, and, moreover, consumers do not object to pay the higher rates for forward. No. 3 Cleveland G.M.B. pig iron has been maintained all this week at 50s. per ton for prompt delivery. No. 1, which used to be only 1s. 6d. per ton above No. 3 in value, and latterly has been 3s. to 3s. 6d. above, is now 4s. above, as it is so scarce, and 54s. must be given for it, while No. 4 foundry is at 48s. 9d., No. 4 forge at 48s. 6d., and mottled and white at 48s. per ton. For delivery over the whole of January 3d. more than these figures has to be paid, and for delivery over the whole of the first quarter about 1s. per ton more, but no one is in any hurry to sell.

Hematite Pig Iron.

The satisfactory condition of the East Coast hematite pig iron is well maintained, and there is every prospect of producers in this branch having an excellent trade in 1911, as consumers of hematite iron are almost all well off for work. Makers will not be held back by having to compete with warrants, for there are none, and it is almost solely the legitimate trade that regulates the fluctuations in the quotations for hematite. For January delivery 64s 6d. per ton is being asked and paid, and for delivery over the first quarter 65s.; while still higher prices are very necessary after that, because the cost of materials is going up, and it is pretty generally acknowledged that there is little profit forthcoming at the figures which are now being realised by the ironmasters. Rubio ore is becoming dearer in price, the merchants having to raise their quotations because the Bilbao mineowners are raising theirs on account of the heavy demand from this country and Germany. Most merchants ask 22s. per ton for good Rubio delivered at Middlesbrough over the next half-year; but there are sellers at 21s. 6d. The imports of foreign iron ore into this district have during 1910 been the best on record. Middlesbrough has received over 2,000,000 tons, against 1,757,351 tons in 1908; West Hartlepool about 275,000 tons, Stockton 240,000 tons, the Tyne upwards of 400,000 tons, and Sunderland about 40,000 tons. The average price of Rubio ore delivered in this district during 1910 has been 20s. 6d. per ton, against 16s. 8d. in 1909 and 15s. 6d. in 1908, and the maximum quotation has been 22s., with 19s. 6d. the lowest. The price now is higher than it has been since 1907. The coke trade is becoming brisker, and is also advanced in price. The heavy stock that had accumulated at the collieries has been disposed of, and the short supply during the holidays has led to exceptional prices being given, but for contracts to be carried out over next quarter 16s. per ton, delivered at Middlesbrough furnaces or equal thereto, has to be given. The lowest price this year has been 15s. 6d. per ton, the highest 18s. 9d.

Manufactured Iron and Steel.

The holidays have interfered with business this week, and also with operations at the works, but at the plate and angle mills the holidays have not been so long as they usually are at Christmas, because there was too much interference with operations during the late shipbuilding lock-out. Nevertheless, the shipyards would have worked more fully this week than has been the case if it had not been that severe weather has interfered with outdoor work, and the call for plates and angles has not been so great as it would have been. The prices are well maintained:—Steel ship plates at £6 15s., iron ship plates at £6 12s. 6d., steel ship angles at £6 7s. 6d., iron ship angles at £7, packing iron and steel at £5 15s., iron ship rivets at £7 7s. 6d., steel bars at £6 5s., iron bars at £7, steel hoops at £6 15s., steel strip at £6 10s., steel joists at £6 5s, steel sheets at £7 7s. 6d. per ton, all less 2½ per cent. It is to be noted that there has been no change in the quotations for iron bars and angles since August, 1909. Galvanised and corrugated steel sheets are firm at £11 5s. per ton for 24 gauge, less 4 per cent. f.o.b. Heavy steel rails are firm at £5 10s. per ton net f.o.b., but the demand has been rather slow lately; nevertheless, manufacturers have enough to keep their mills in full operation.

Shipbuilding.

There is abundance of work at the shipyards in this district, as might be expected after the lengthy stoppage due to the recent labour dispute. Instead of having a week or a fortnight's holiday as is usual at this time of the year, most yards have been closed only one day this week, and will be laid off on Monday only next week; but in a few cases Monday and Tuesday in each week are allotted as holidays. The men having been so long idle, are very short of funds, and are content that the holidays should be short. They are well assured of continued full work over next year, and builders expect to be able to secure higher prices, otherwise they would not have offered advances of wages and have

arranged that there shall be no further change until 1916. There is every prospect that 1911 will be almost, if not quite, as good a year as 1907 was, and that was the busiest time on record for shipbuilders. The leading shipping lines have all ordered new steamers, owners of tramp steamers have latterly come forward briskly for new tonnage, and there is a very large amount of naval work booked for our own and other Governments. The shipbuilding of the closing year, notwithstanding the interruptions caused by the lock-out in this district and Scotland, has, for the whole of the United Kingdom, exceeded that of any year since 1907, but is below that reported in the years between 1898 and 1907. In the North-East of England 226 vessels were launched in 1910, of, altogether, 654,769 tons, whereas the output in the previous year was 216 vessels, of 494,798 tons. The Tyne builders launched 78 vessels; the Wear, 58; the Tees, 65; West Hartlepool, 21; and Blyth, 4.

Engineering.

The engineering firms are well off for orders for next year's execution. They are not so far behind with their contracts as the shipbuilders, and did not suffer much from the labour troubles at the shipyards. The holidays, therefore, are more prolonged than at the shipyards. Palmer's engine works and boiler shops are closed for eight days, the Wallsend Slipway and Engineering Company's men will be off for ten days, and the North-Eastern Marine Engineering Company's for a fortnight. The leading marine engineering establishments in the North-East of England in 1910 have supplied 196 steamers with engines of 436,794 horse-power, as compared with 170 vessels with 358,724 horse-power in 1909. Richardsons, Westgarth and Co. have engined 36 vessels; the North-Eastern Marine Engineering Company, 50; Blair and Co., Limited, 22; Central Marine Engineering Company, 13. The building of the new transporter bridge over the Tees at Middlesbrough is making rapid progress, and Mr. S. E. Burgess, the borough engineer, reports that the total value of the work already done is £56,912.

North-Eastern Railwaymen and Non-unionism.

The men on the North-Eastern Railway seem to be taking things with a very high hand, and it appears as if there would be a general strike over the question of non-unionism. The federation of all the district councils on the system has now approved the men's proposal to refuse to work alongside non-unionists on a given date, which has not yet been fixed. The feeling amongst society members is reported to be so strong that the Executive Council of the Amalgamated Railway Servants is not expected to place obstacles in the way of the North-Eastern men carrying out their intentions.

Coal and Coke.

Though the holidays at the collieries have kept consumers out of the market, there is a distinctly better feeling all round, and traders speak very hopefully of the prospects for the first half of next year. The half year that is closing this week has been a poor time, both as regards demand and prices, but has brightened considerably during the last month, and steam coals have been raised to 9s. 9d. per ton, f.o.b., for best, while best Durham gas coals are up to 9s. 3d., f.o.b. Coke also is dearer. Sir D. Hassell, the umpire, has awarded the Durham miners 2½ per cent. advance of wages, and that leaves wages at the close of the year 1¼ per cent below those ruling at the commencement. In January wages were reduced 6¼ per cent., in May they were advanced 2½ per cent., and in December another 2½ per cent. was given.

NOTES FROM SCOTLAND.

(From our own Correspondent.)

The Pig Iron Warrant Market.

There has been a holiday feeling in the pig iron warrant market, which was closed from Friday till Wednesday for the Christmas holiday, and will be suspended for a similar time for the New Year stoppage. Since last report business has been done in Cleveland warrants at 49s. 0½d. and 49s. 10½d. cash, 50s. 1d. to 50s. 2½d. one month, and 50s. 8½d. and 50s. 9d. three months. A considerable extra amount of Cumberland hematite at 66s. 3d. to 66s. 4½d. one month and 66s. 11d. three months. It is reported on 'Change that the recent purchases of hematite are likely to go to augment the stocks in Cumberland, but it is thought that this, if correct, may be only a temporary arrangement, as an increased inquiry for the class of iron is anticipated on the part of consumers.

The Scotch Pig Iron Trade.

Current business in Scotch pig iron has been small, and G.M.B. iron is scarcely so firm as last week, but the values of special brands are well maintained. Free at ship in Glasgow Harbour, Govan and Monkland, Nos. 1, are quoted 57s.; Nos. 3, 56s.; Carnbroe, No. 1, 60s. 6d.; No. 3, 57s. 6d.; Clyde, No. 1, 62s.; No. 3, 57s.; Gartsherrie and Calder, Nos. 1, 62s. 6d.; Nos. 3, 57s. 6d.; Summerlee, No. 1, 64s. 6d.; No. 3, 59s. 6d.; Langloan, No. 1, 65s.; No. 3, 60s.; Coltness, No. 1, 82s. 6d.; No. 3, 61s.; Shotts, at Glasgow or Leith, No. 1, 63s.; No. 3, 58s.; Eglinton, at Ardrossan or Troon, No. 1, 57s. 6d.; No. 3, 56s. 6d.; Glengarnock, at Ardrossan, No. 1, 64s.; No. 3, 59s.; Dalmellington, at Ayr, No. 1, 60s. 6d.; No. 3, 58s.; Carron, at Grangemouth, No. 1, 63s. 6d.; No. 3, 58s. 6d. per ton. Since last report one hematite furnace has been put out of blast, and there are now 44 producing hematite, 36 ordinary and special brands, and 5 basic iron, the total of 85 furnaces thus in operation in Scotland comparing with 86 last week, and 83 at this time last year.

The Shipments of Pig Iron.

The shipments of pig iron from Scottish ports in the past week amounted to 5377 tons, being 485 tons more than in the corresponding week of 1909. Arrivals at Grangemouth of pig iron from Cleveland and district reached 9210 tons, showing an increase of 1015 tons compared with the quantity received in the corresponding week of last year.

The Hematite Trade.

Business in hematite has been more active. As stated above, the transactions in Cumberland hematite have been very considerable—indeed, larger than for a long time past, and the prices have been improving. More attention is also being paid to Scotch hematite, the consumption of which is expected to be much increased in the early part of the year. Makers are understood to have large commitments under existing contracts. Fresh business is necessarily limited by the holidays. Makers are firm in their ideas of price, and merchants quote 70s. to 70s. 6d. for delivery at West of Scotland steel works.

Finished Iron and Steel.

The finished iron and steel works are now closing down for the holidays, and it is not expected that work will be resumed, except in urgent cases, until Monday, 9th January. There has been comparatively little fresh business this week. Steel makers are now well supplied with orders, as a rule, so that they have little or no anxiety for the future, apart from the probable cost of the raw material. There is a general impression in steel circles that the coming year is to be one of the busiest in the history of the trade, if, indeed, it does not quite eclipse all former ones in the amount of its production. Apart from the heavy requirements in shipbuilding material, for which, in most instances, arrangements, it may be presumed, have already been made, inquiries from abroad would seem to indicate that the foreign business in general structural material may prove of special importance. For the present America is somewhat of an enigma, and no one can possibly say how far the coming year may find her in the world competition for steel, local resources not being so elastic as in some former times. Much is expected from the development of business in the countries of South America, as well as of Canada and the Colonies.

The Coal Trade.

In the past few days there has been much activity in the coal trade. Shippers have been exerting themselves to get cargoes cleared this week, because most of the docks will be closed several days next week. Shipments are well up to the recent average. Coastwise cargoes and shipments to Irish ports form the great bulk of the business, foreign exports being comparatively light. At Glasgow Harbour steam coal is quoted f.o.b. from 9s. 6d. to 10s.; ell or household qualities, 10s. to 10s. 3d., and splint, 10s. to 10s. 9d. per ton. These prices are a good sample of those prevailing at all the Scottish ports for coals of similar quality. A large business has been done in house coal for home consumption, and prices for all qualities are well maintained.

WALES AND ADJOINING COUNTIES.

(From our own Correspondent.)

The End of the Strike.

On Saturday there was a momentous interview at Cardiff. A strong deputation of representatives from each of the colliery districts, accompanied by Mr. Stanton, the miners' agent, waited on Mr. Hann, general manager of the Powell Duffryn Company, and informed him that they had agreed to fall in with the suggestion of the Executive Council of the South Wales Miners' Federation, and accept the conditions laid down in the resolution of the Conciliation Board passed on November 14th, and had come to him in order to make arrangements for the resumption of work. In the course of the interview which followed Mr. Hann said it was the intention of the company to close the Treaman Colliery, which was unremunerative, but he would see that as many of the men as possible should find employment in the other collieries as fast as it was possible for them after the resumption of work. Some minor matters were next discussed; the repairers to go down at once, so that the surface men could complete the stalls for the workmen to start without any delay, the horses to be taken down on Wednesday. This practically ends the strike, though some little time will be occupied in completing arrangements; but the attitude of the men, the strike committee, and, in fact, all interested, gives assurance that the peace now entered upon will be satisfactory, and, for the public good, lasting.

Last Week's Coal Trade.

Large tonnages arrived, delayed by the storms, and a busy week was experienced. Colliery owners were all heavily booked; sales, even at fancy prices, few. Forward business was livelier on account of the settlement of strike, and practical evidence of this was given by the restarting of Aberdare pits on Monday and the production of coal. Firm prices expected for the first fortnight in the new year. Small coal strong; house steady. No. 2 Rhondda firm. Steam coals and Monmouthshire strongly held.

The Coal Trade: Present Quotations.

The holidays and festivities have quite disturbed the ordinary round of business, and on Monday it was reported at Cardiff that the Saturday quotations were to be regarded as the latest trustworthy notices, Bank holiday being a closed day on 'Change. Latest:—Best large steam, 16s. 6d. to 17s.; best seconds, 16s. to 16s. 6d.; ordinaries, 15s. 3d. to 15s. 9d.; best drys, 16s. to 16s. 6d.; ordinary drys, 16s. to 16s. 9d.; best washed nuts, 14s. to 14s. 6d.; seconds, 13s. 3d. to 13s. 9d.; best washed peas, 12s. to 13s.; seconds, 10s. 6d. to 11s. 6d.; best bunker smalls, 9s. 6d; best ordinaries, 8s. 6d. to 9s.; cargo smalls, 7s. 9d. to 8s. 3d.; inferiors, 7s. to 7s. 6d.; best Monmouthshire black vein, 15s. to 15s. 6d.; ordinary Western Valley, 14s. 3d. to 14s. 6d.; best Eastern Valley, 13s. 3d. to 13s. 9d. Bituminous: Very best households, 17s. 6d. to 18s.; best ordinaries, 14s. 6d. to 16s. 6d.; No. 3 Rhondda, 17s. to 17s. 6d.; brush, 13s. 3d. to 13s. 9d.; smalls, 9s. 6d. to 10s.; No. 2 Rhondda, 12s. 6d. to 12s. 9d.; through, 10s. to 10s. 6d. Patent fuel, 14s. 9d. to 15s. 6d. Coke: Special foundry, 24s. to 26s. 6d.; foundry, 18s. to 20s.; furnace, 16s. 3d. to 17s. 3d; pitwood, ex-ship, 19s. 6d. to 20s.

Newport, Mon., Coals.

Heavy tonnages coming in caused much activity. Latest approximate quotations:—Very best black vein, 14s. 9d. to 15s. 3d.; Western Valley, 14s. to 14s. 3d.; Eastern, 13s. to 13s. 6d.; other kinds, 12s. 3d. to 12s 9d.; best smalls, 7s. 3d. to 7s. 9d.; seconds, 6s. 9d. to 7s. 3d.; inferiors. 6s. 3d. to 6s. 9d. Bituminous:—Best households, 15s. 6d. to 16s. 6d.; seconds, 14s. to 15s.; patent fuel, 14s. 6d. to 15s. Coke: Foundry, 18s. to 19s.; furnace, 16s. 6d. to 17s. 3d.; pitwood, 19s. 6d. to 20s.

Swansea Coals.

The storms have at length lessened, and the port has had a very active time. Latest Saturday quotations:- Slack time in anthracite; patent fuel well maintained. Best anthracite, 22s. to 24s. net; second malting, 18s. to 21s. 6d. net; big vein, 15s. 6d. to 17s., less 2½; red vein, 11s. 6d. to 12s., less 2½; machine-made cobbles, 21s. to 23s. net; Paris nuts, 23s. to 25s. net; French nuts, 23s. to 25s. net; German nuts, 23s. to 25s. net; beans, 19s. 6d. to 21s. net; machine-made large peas, 10s. 6d. to 11s. net; fine peas, 9s. to 10s.; rubbly culm, 5s. 3d. to 5s. 9d., less 2½; duff, 2s. 6d. to 3s. net. Steam coal: Best, 17s. to 18s.; seconds, 13s. 6d. to 15s.; bunkers, 10s. 3d. to 11s. 6d.; small, 6s. 9d. to 7s. 6d., all less 2½. Bituminous: No. 3 Rhondda, 18s. to 18s. 6d.; through, 15s. to 15s. 6d.; small, 10s. to 11s.; patent fuel, 13s. 3d. to 13s. 6d., all less 2½.

Iron and Steel.

Dowlais would appear to be making up for the slackness in the trade of other parts of the district, as during the week a considerable degree of activity was seen in all directions at furnaces and mills, and the despatch kept the locomotive department busy. There was considerable business done in traffic arrangements, the anxiety being evident both at port and railway to get as much completed as possible before the Christmas festivities. Market quotations not issued in time. Rubio ore, 20s. 6d. to 20s. 9d.

Tin-plate.

Good substantial work was done at the mills last week, with the result that the make totalled nearly 90,000 boxes, and the receipt from works 90,207 boxes. Stocks in vans and warehouses amount to 172,362 boxes. Loading is going on strongly for Antwerp and Rotterdam, Batoum, Odessa, and New York. The trade remains in a firm and buoyant condition, and the reports from all parts of the district are equally satisfactory. Quotations were not issued in time this week for our despatch.

NOTES FROM GERMANY, FRANCE, BELGIUM, &c.

(From our own Correspondent.)

Rhenland-Westphalia.

Activity remains satisfactory in the various departments, and orders booked for the first quarter secure employment to the mills and factories for some time ahead. In semi-finished steel both inland and foreign demand are lively. The heavy sorts of railway material are in rather weak request, and there is a slight dulness felt in this branch, owing to limited purchases on the part of the Prussian State Railways. Sectional iron is in quiet but regular demand on home account, while a lively business continues to be done for abroad.

The Silesian Iron Market.

Official accounts recently given show the pig iron trade during the third quarter of the present year to have been satisfactory, output being readily consumed; prices have tended upwards, and there was generally more strength felt. Irregular employment is reported from the bar mills, the heavier sorts being neglected; rates, consequently, have been a shade easier than before. A falling off in demand was noticeable for wire and wire articles; prices, nevertheless, have remained unchanged. In the pipe trade a fair activity is reported, but prices are below the costs of production. Silesian business with Austria and with South Germany has improved as compared with previous years. Heavy plates have remained languid, whereas sheets meet with improving demand at raised prices; fresh orders come in freely. A slow trade was done in rails. Only light section rails have been rather better inquired for than in previous quarters.

From the Siegerland.

Employment continues satisfactory, but the prices for raw material have not improved. Output and consumption in iron ore have developed satisfactorily. In iron ore deliveries have been higher than production, but the basis prices of M. 11.60 p.t. for raw spathose ore and M. 16.60 p.t. for roasted ditto are not remunerative. The Siegerland rolling mills are well supplied with orders, and at pretty good prices too.

Coal in Germany.

Demand and prices have continued satisfactory, both for engine and house coal. Coke, likewise, is in strong request.

Austria-Hungary.

All the principal departments of the iron and steel industry are satisfactorily occupied, and the outlook is reported to be fair in most trades. In coal also a good deal of animation was felt last week.

Firmness in Belgium.

There is every indication of a good business being done in the next quarter, more strength being noticed in all departments. The demand for bars in basic has shown a slight falling off, and makers find it difficult to carry the raised prices; increasing stiffness is felt in plates, and rails also continue in active request. Semi-finished steel, as well as scrap iron, are in good call at tolerably firm rates. The Belgian coal market shows a strong tone, and activity is very lively; the want of wagons, however, prevents a full development of the coal trade.

Healthy Business in France.

Though the expectations generally entertained regarding the iron trade in the last two quarters of the year have only partially been fulfilled, still the outlook has, on the whole, continued fair, both concerning orders and employment, and the condition of prices will also remain firm in the next quarter. The large iron works in the East Departement report prospects for next year to be good, and the position of the iron industries in the Loire district is very healthy. Sales for 1911 are effected at the prices now ruling. In the Paris retail business the following prices are quoted:—160f. to 175f. p.t. for merchant bars; 190f to 195f. p.t. for hoops; 190f. to 200f. p.t. for girders; and 195f. p.t. for 3 mm. plates. The construction shops report fresh orders to come in freely from the large railway companies. In the French coal trade also the want of wagons is very keenly felt, causing a slight weakness in prices in the Nord. The Loire and Centre collieries report a satisfactory condition, output being very strong and rates firm.

AMERICAN NOTES.

(From our own Correspondent.)

New York, December 21st.

A large part of the Gary plant has closed down awaiting the demand that will warrant heavier output. No one looks for lower prices in any direction. Most of the accumulated pig iron is protected by bank loans, so that large blocks of iron will not be thrown on the market. Western Pennsylvania furnaces especially have been holding large blocks of iron for several months, and it looks as if they would have to hold it some time longer. Basic and Bessemer are watched closer than foundry or forge. The larger consumers count on mid-winter reductions. They argue that with half the capacity idle nothing else is to be expected. The makers of iron and steel propose to meet this emergency by reducing production farther if necessary and simply holding on at present prices. It is a game of hold off at one side as to buyers and to hold on at the other side. None of the reports are encouraging, and the situation will remain for some weeks to come about where it is unless the large consumers change their minds. Plate and structural material are held at old quotations, notwithstanding that half the capacity is idle. The Norfolk and Western Road is in the market for 10,000 tons of bridge material, the Rapid Transit Company of this city for 15,000 tons and a larger quantity of rails. The new post-office at the Pennsylvania will take 6200 tons, and the new building for engraving and printing at Washington, D.C., will take 5000 tons. Several large orders for underframes and other car building material for southern railroads will help to strengthen the structural iron situation, which is badly in need of help. A number of orders for smaller quantities for building material will be placed during the week.

A large eastern steel concern is in the market for 50,000 tons of coke. Another concern running furnaces is about to close a contract for enough coke to run it for six months. The coke trade is exceptionally quiet. Some rod mills which have been idle have recently resumed, and the demand for wire products is once more gaining ground. The copper market shows very little change. The announcement made a few weeks ago of a marked copper curtailment has not been verified. Various reasons have been given why the maximum output has been maintained. Present production will probably continue, and a weak market is therefore to be looked for. Tin-plate is firm, yet there is no heavy demand. Tin is moving normally, and prices are fractionally higher than a week ago. Lead moves with regularity and without change in price.

PERSONAL AND BUSINESS ANNOUNCEMENTS.

Dr. Heinr. Traun and Sons inform us that they are removing from 8, Redcross-street, E.C., to larger premises at 23A, Goswell-road, E.C.

Mr. C. I. Davidson, of 10, Fenchurch-avenue, E.C., advises us that on the 1st of January, 1911, he is removing to more convenient offices at No. 18, Billiter-street, London, E.C., telephone No. 7 Eastern, where his business of consulting engineer, naval architect and surveyor, will be conducted.

We are asked to state that on and after January 1st next Messrs. Felten and Guilleaume's agency for insulated wires and cables for electric lighting and transmission of power, and for rail bonds and rubber manufactures, will be conducted under the name of Mr. Reginald R. Todd at 334, Birkbeck Bank-chambers, W.C.

BRITISH PATENT SPECIFICATIONS.

When an invention is communicated from abroad the name and address of the Communicator is printed in italics.

When the abridgment is not illustrated the Specification is without drawings.

Copies of Specifications may be obtained at the Patent-office Sale Branch, 25, Southampton-buildings, Chancery-lane, London, W.C., at 8d. each.

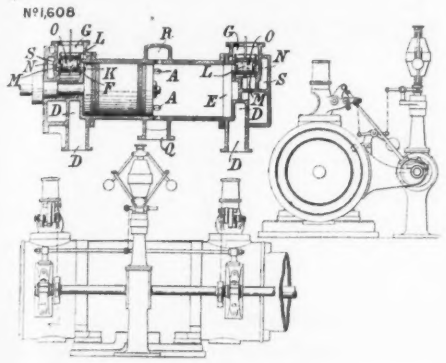
The first date given is the date of application; the second date at the end of the abridgment is the date of the advertisement of the acceptance of the complete specification.

Any person may on any of the grounds mentioned in the Acts, within two months of the date given at the end of the abridgment, give notice at the Patent-office of opposition to the grant of the Patent.

STEAM ENGINES.

1608. January 21st, 1910.—IMPROVEMENTS IN STEAM ENGINES, Frank Everard Musgrave, of Globe Ironworks, Bolton, Lancaster.

The exhaust ports A are arranged midway of the length of the cylinder and are controlled by the piston. The end covers are formed with steam chambers D and with extensions E into which the piston heads pass at the ends of its strokes so that the steam jackets constituted by the chambers D extend over those parts of the cylinder adjacent to the inlet ports F, and uncovered by the piston during admission. The valve chambers G formed in the upper parts of the covers are each fitted with a liner H formed with two sets of ports, and adapted to receive a piston valve L, the rings M of which are spaced apart so that the lower ports K which open into a surrounding space N, communicating

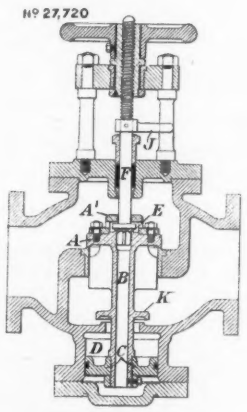


through the ports F with the cylinder, will be in communication with the upper ports, which are in the steam supply space, or will be cut off therefrom according to the position of the valve. The valves L have passages through them so that the pressure above and below them is equalised; such passages are indicated by dotted lines at O. The steam inlets D to the chambers G in the cylinder covers are preferably at the underside as shown, as is also the branch Q from the annular space R around the exhaust ports A. In the outer end portions of the covers are formed, in known manner, chambers S which are connected to the cylinder through non-return valves (not shown) which may be capable of operation by external means, the arrangement being designed to afford additional clearance spaces when the compression is high as in starting when the cut-off is late. These spaces which normally contain air, act as heat insulators. Conveniently there may be a slight clearance around the piston heads so that they do not come in contact with steam-jacketed portions of the cylinder. The valves may be operated, as illustrated, in side and end elevation respectively.—*December 7th*, 1910.

STEAM GENERATORS.

27,720. November 29th, 1909.—IMPROVEMENTS IN AND RELATING TO STOP VALVES, John Auld, of Whitevale Foundry, Rochester-street, Glasgow.

The main valve A is formed with a hollow spindle B extending downwards and having a piston C secured at lower end preferably of the same, or a greater area than the main valve, and working in a chamber D at the bottom end of valve chest. A small "pilot" valve E is fitted centrally over the main valve A at the top of the hollow spindle B inside the main valve chest, and this pilot valve would close the top end of the hollow spindle when the main valve is closed. The pilot valve E is attached to the lower end of a spindle F operated by a screwed thread with hand wheel at the top end, and an arm J with projecting fork to bear against the stationary part is mounted on spindle F so as to prevent the spindle and pilot valve

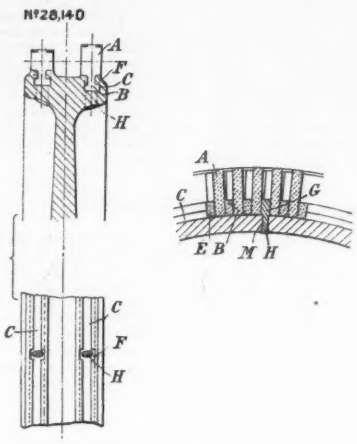


from turning when the hand wheel is turned, and thus prevent the pilot valve face from being cut up by frictional wear in opening and closing. With this arrangement of mechanism and parts the pilot valve E would be opened first to admit initial pressure steam through the hollow spindle B to the underside of the piston C, situated at the bottom end of spindle, so that the main valve A will thus be balanced and easily opened up with a minimum degree of strain. The main valve in the construction illustrated is opened by the valve E engaging with the housing or bridge piece A^1 on the main valve, so that the auxiliary valve is bound to open before and to close after the main valve in the known manner. A cover or shield K is formed on the hollow spindle B to prevent dirt, grit, or other foreign matter from being blown into cylinder D, where it might interfere with the action of the main valve piston C.—*December 7th*, 1910.

TURBINES.

28,140. December 2nd, 1909.—IMPROVEMENTS IN OR RELATING TO BLADE-FIXING DEVICES FOR ELASTIC FLUID TURBINES, *Aktiengesellschaft Brown, Boveri et Cie., of Baden, Switzerland.*

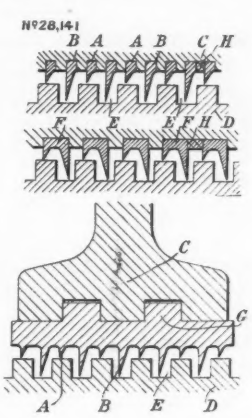
The blades A are formed with T-shaped roots B, which engage in correspondingly shaped slots C formed in the rotor, the blades and distance pieces E being inserted in the slot through the opening F, placed at any convenient part of the periphery of the rotor, the slot F being of constant breadth to allow of easy withdrawal of the blades and distance pieces. A special distance



piece G is provided to fit into this point F of the slots, this distance piece having a projecting nipple H, which passes through a hole M in the rotor, and being secured to the rotor by suitable means. The blades and the distance pieces having been assembled in the slots of the rotor in the usual manner, the last distance piece G is inserted in the opening F, so that the nipple portion H passes through the hole M, and is then secured by riveting from the underside of the rotor. In carrying out the reverse operation of dismantling the rotor the special distance piece G is removed first, thereby permitting the removal of the other blades and distance pieces through the opening F.—*December 7th*, 1910.

28,141. December 2nd, 1909.—LABYRINTH PACKING, *Aktiengesellschaft Brown, Boveri et Cie, of Baden, Switzerland.*

The packing rings A and B are separately mounted in the member C. The rings A only extend to the outer surface of the opposite member D, whilst the rings B engage to a considerable extent in the grooves E of the member. By combining the two

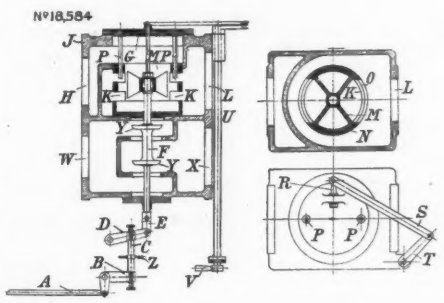


rings A and B, so that they form one single ring F, the form of construction illustrated in the middle engraving is obtained. The rings are secured in a known manner, for instance, by means of a caulking strip H as shown between the last two rings. The whole row of rings can be constructed specially in one or several pieces G, and then be inserted as shown in the lower engraving.—*December 7th*, 1910.

INTERNAL COMBUSTION ENGINES.

18,584. August 6th, 1910.—IMPROVEMENTS IN GOVERNOR VALVES FOR INTERNAL COMBUSTION ENGINES, Kenneth Irwin Crossley, of Crossley Brothers, Limited, Openshaw, Manchester, and James Hutton, of 14, Henshaw-street, Stratford.

The governor of the engine operates through the rod A, bell crank lever B, adjustable rod C, lever D, and link E to the gas throttle

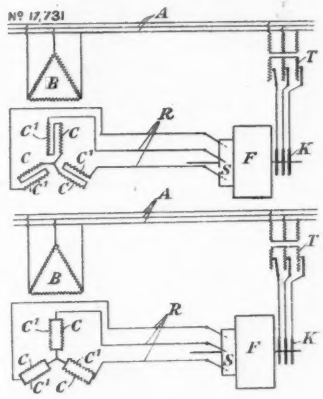


valve F, and air throttle valve M. Air is admitted through the opening H in the valve box J, and passes through the ports K to the entrance to the air pipe at L. The air may be adjusted by hand by giving a twisting movement to the valve M. This valve is placed inside a liner N, in which are formed ports O corresponding with the ports in the valve. These ports do not extend all round the circumference of the valve, and the air can therefore be throttled as required by twisting the valve by hand. The twisting movement is given to the valve by means of the pegs P fixed in the disc G, which latter may be moved to the required position by means of the stud R, link S, lever T, rod U, and hand-operating lever V. The outlet from the valve box, from which the air is led to the inlet valve, is shown at L. Gas enters at W, and passes through the gas throttle valve F through the port X, whence it is led to the engine inlet valve. This gas throttle valve F has its closing edges rounded, as shown at Y, to enable the quantity of gas passing through the valve—which is dependent on the position of the engine governor weights—to be varied for different loads, and enables the proportion of gas in the mixture to be decreased as the load on the engine is reduced. To enable the valves to be closed or moved to any position independent of the action of the governor, the end of the lever B is fitted with a right-hand nut, and the lever D is fitted with a left-hand nut as shown. Rotation of the hand wheel Z on the rod C moves the valves by the action of these nuts to any desired position. Stops are fitted to the ends of the rod C to limit the movement of the valves to that given to them by the engine governor.—*December 7th*, 1910.

DYNAMOS AND MOTORS.

17,731. July 26th, 1910.—IMPROVED ARRANGEMENTS FOR CONTROLLING THE SPEEDS OF INDUCTION MOTORS, Siemens Brothers, Caxton House, Westminster, S.W.

In both the engravings the three-phase supply mains are denoted by A, the delta stator winding of the induction motor, the speed of which is to be regulated by B, the starred rotor winding of the latter by C and C^1, the frequency transformer by F, having commutator S and slip rings K, an adjustable voltage transformer by T, and the mains connecting C and C^1 to the com-

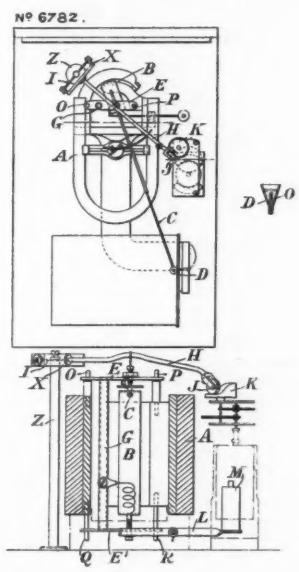


mutator brushes of S by R. The upper engraving shows the arrangement for the higher speed when C and C^1 are connected in series. The lower engraving, on the other hand, shows the arrangement for the lower speeds when C and C^1 are connected in parallel. The frequency transformer F merely acts to transform the frequency of A into the frequency required by R, namely, into the slip ring frequency of the induction motor, the speed of which is to be regulated. The motor which drives it need only be small, as only its internal losses, such as friction and hysteresis loss, have to be supplied by this motor. Sometimes in known manner F may be driven by means of a polyphase winding situated on its stator and suitably connected to a source of electrical power.—*December 7th*, 1910.

TESTING AND MEASURING INSTRUMENTS.

6782. March 17th, 1910.—IMPROVEMENTS IN OR RELATING TO MOVING COIL ELECTRICAL RECORDING INSTRUMENTS, *Compagnie pour la Fabrication des Compteurs et Matériel d'Usines à Gaz, of* 16 *and* 18, *Boulevard de Vaugirard, Paris, France.*

The pen is formed with a capillary tube D fitted with a wick O for limiting the flow of ink. A is a permanent magnet producing a field on which turns the moving coil B carrying the indicator hand C which terminates in the recording pen D. The moving coil B is supported by a separate frame formed in substance of two horizontal brass cheeks E E^1 situated at each side of



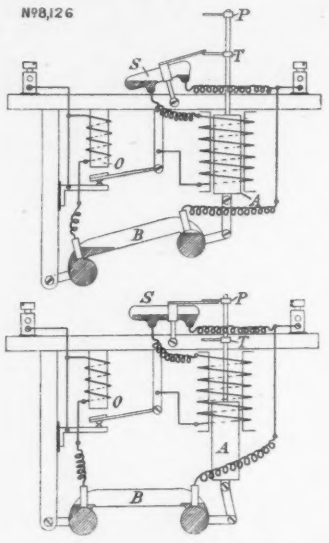
the coil B and magnet A and connected together by a vertical tube G. The cheeks E E^1 are formed near their ends with holes whereby they can slide on guide rods O, P, Q, R, fixed above and below the magnet respectively. The sliding frame carrying the points is suspended by the cheek E from a rod H terminating at one end in a fork adapted to pivot about a horizontal rod I fixed to a vertical pillar Z. At its other end the rod H carries a roller J resting on a cam K rotated through suitable gearing by a small auxiliary motor. It is only during the very short time in which the lowest part of the cam K passes under the

roller J that the reservoir pen D rests on the band of paper and marks a point thereon. In order to facilitate and accelerate the lifting of the moving coil when a higher part of the cam comes under the roller J, below the magnet a lever L is used, pivoted at the middle about a horizontal axis in fixed connection with the frame of the instrument and carrying at one end a counterweight M, while its other end bears against the middle of the bar E^1 and tends to lift the same. Instead of the counterweight M a spring may be employed.—*December 7th* 1910.

LIGHTING AND HEATING.

8126.. April 4th, 1910.—IMPROVEMENTS IN CONNECTION WITH SHUNT-CIRCUIT TILTING DEVICES FOR MERCURY VAPOUR LAMPS, *W. C. Heraeus, G.m.b.H., of Hanau, on the Maine, German Empire.*

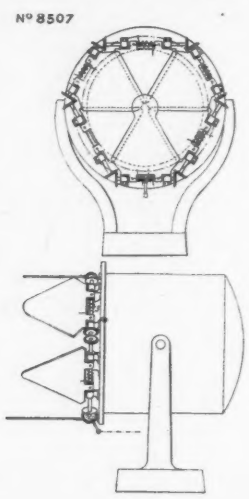
The upper engraving shows the whole arrangement at the instant when the tilting motion has been effected without the lighting of the lamp having taken place, and before the lamp commences to return to its normal position. The lamp B is raised by the shunt armature A. The switch S, which is illustrated as a mercury switch, has been brought into the open circuit position by the rod T, which is rigidly connected with the shunt armature. The



switch O, to be operated by the main current, has remained closed, because the main current failed. When, therefore, the lamp returns to its normal position, the rod P returns the switch S to the closed circuit position, and the tilting motion is repeated. If the main current comes into action, the switch O switches out the shunt current electro-magnetically, and the lamp returns automatically to its normal position The mechanism may be varied in its details, and the switches O and S can be combined in one, and can be switched in and out electro-magnetically by the main current, or mechanically by the tilting mechanism on the completion of the tilting motion.—*December 7th*, 1910.

8507. April 8th, 1910.—IMPROVEMENTS IN OR RELATING TO SEARCHLIGHTS OR PROJECTORS, Siemens Brothers' Dynamo Works, Limited, of Caxton House, Tothill-street, Westminster, S.W.

This invention relates more particularly to arrangements in

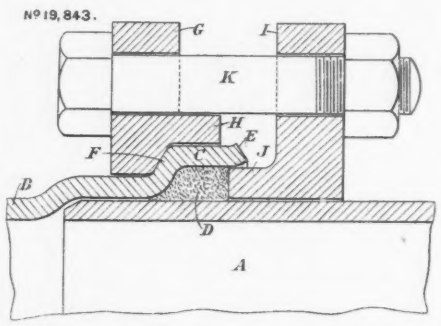


which converging hinged shutters are used to enable the light to be shut off or turned on instantly, for instance, at short intervals of time, as in signalling. In known arrangements of this kind in signalling lamps it has been proposed to provide four triangular flaps or shutters, one at each side of a square window or light aperture, these being adapted to move simultaneously in a definite order, and to meet and overlap at the centre when closed, whilst when open they would stand clear of the light aperture. A somewhat similar arrangement has also been proposed in photographic cameras, and in this connection it has been suggested to use more than four shutters. The main object of the present invention is to enable such an arrangement to be conveniently applied to the circular barrels of ordinary projectors or to polygonal barrels—that is, barrels having more than four sides. To this end the front or light aperture of the projector has provided around it flaps or shutters, which are all V-shaped or sector-shaped, and are acute-angled at their tips—that is to say, opposite their bases or hinged sides. These acute-angled flaps are all operated by one common actuating mechanism, their hinge-pins or axles being geared together, and the axles of alternate flaps or shutters being arranged at different distances from the centre. By reason of all the flaps or shutters being acute-angled, their number, in order to completely cover the circular or polygonal light aperture, necessarily exceeds four, and may conveniently be six or more, and hence their bases or hinged sides can be made narrower than would otherwise be possible, so that they pack better round the front or window of the projector. The opening and closing apparatus may be combined with springs, which, when the flaps have been moved one way by hand, will effect or assist the subsequent return movement.—*December 7th*, 1910.

MISCELLANEOUS.

19,843. August 25th, 1910.—IMPROVEMENTS IN OR RELATING TO PIPE JOINTS, the British Welding Company, Limited of 25, Victoria-street, Westminster, London, S.W., and Ezekiel Grayson Constantine, of 87, Tulse-hill, London, S.W.

As shown, the pipe lengths A and B are fitted together in the usual spigot and faucet fashion, the faucet end being formed with an enlarged projecting portion C extending parallel to the pipe A, and forming therewith a stuffing-box for the reception of packing material D, the portion C being upturned at E, and being inclined



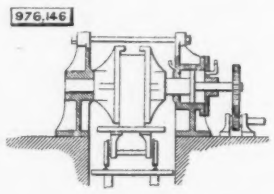
or curved at F to form a shoulder, which is engaged by a loose flange or collar G having a projecting portion H extending partly over the portion C. A loose gland or collar I having a projecting portion J for engagement with the packing material D, is mounted on the pipe length A, and is adapted to be tightened by means of nuts or bolts K passing through the collars as usual. By the provision of the projecting portion H on the loose flange G, the support afforded to the stuffing-box formed on the pipe B permits thinner material to be used in the pipes than if unsupported.—*December 7th*, 1910.

SELECTED AMERICAN PATENTS.

(From the United States Patent-office Official Gazette.)

976,146. METHOD OF TREATING METAL INGOTS, *J. A. Brinell, Stockholm, Sweden.—Filed January 10th*, 1908.

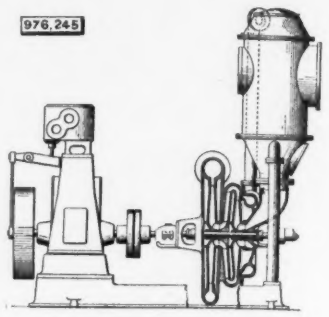
The ingot is kept in slow rotation under pressure while it is



cooling to prevent segregation and secure homogeneity. It is one of two very similar patents. There are four claims to each.

976,245. CONDENSER SYSTEM, *L. R. Alberger, Greenwich, Conn., assignor to Alberger Condenser Company, New York, N.Y., a Corporation of New York.—Filed November 6th*, 1908.

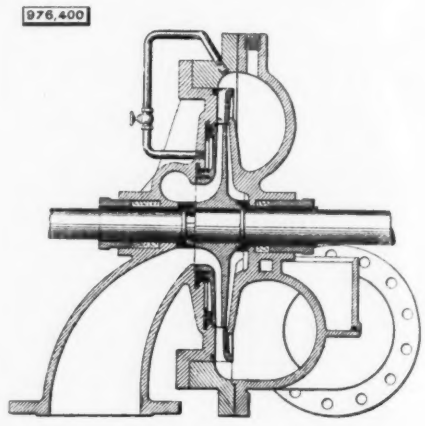
This patent is for the combination in a condenser, in which the water is removed separately from the air with a condenser, of a centrifugal or turbine pump for removing the condensing water and the water of condensation, this pump having a plurality of impellers, that which first acts on the water causing it to increase the velocity of its flow, and means whereby the accelerated flow of water inductively withdraws air from the condenser and commingles it with the water between the impellers, so that this air may be compressed, and the combined air and water may be



pumped by the other impeller or impellers. There are fifteen claims.

976,400. CENTRIFUGAL PUMP, *R. Salzer, Trenton, N.J., assignor to the De Laval Steam Turbine Company.—Filed April 7th*, 1906. *Renewed September 20th*, 1910.

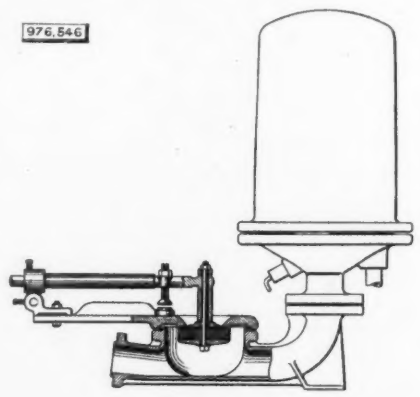
In a centrifugal pump, and in combination with an impeller and a casing therefor having walls forming an annular passage beyond the impeller outlet, a diffuser formed of a flat ring and vanes



secured at their edges to and extending across this ring, the diffuser being seated in the annular passage and having the exposed edges of its vanes abutting against a prolongation of one of the casing walls forming the passage; and a second ring of less width than the first named ring secured to edges and supported on the last named wall. There are eight claims.

976,546. HYDRAULIC RAM, *B. J. Carroll, New York, N.Y., assignor to Power Specialty Company, New York, N.Y., a Corporation of New York.—Filed December 30th*, 1909.

The nature of the patent will be easily understood from the

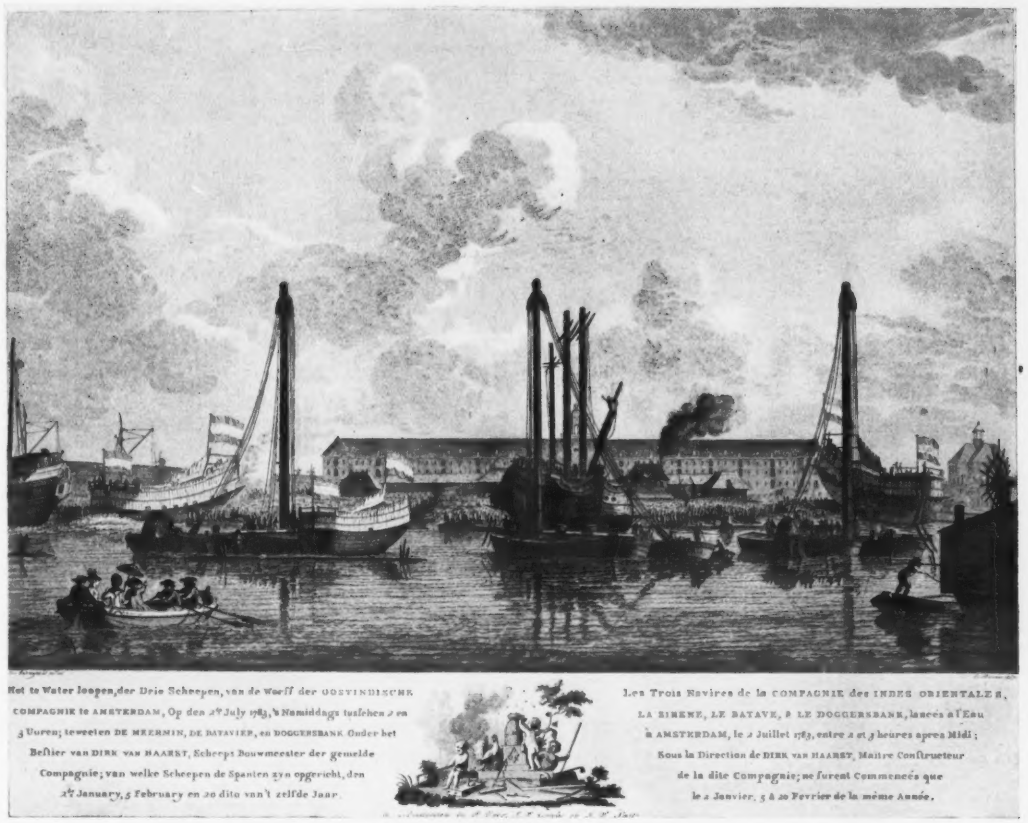


drawing. It refers to the way in which the beating valve is guided, and loaded to make it fall open. There are seven claims.

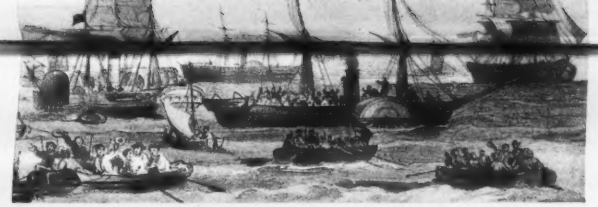
END OF VOL. CX.

SHIPBUILDING AT AMSTERDAM—PAST AND PRESENT

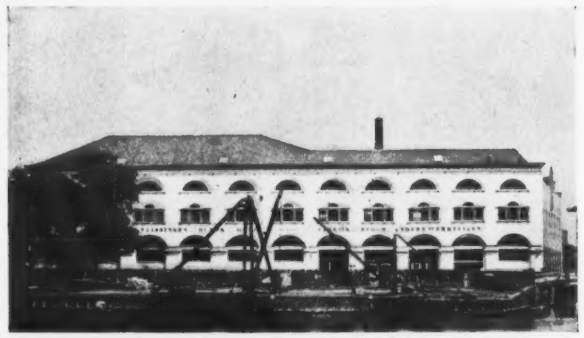
WHARF AND WAREHOUSE OF THE EAST INDIA COMPANY—XVIII. CENTURY


Het te Water loopen, der Drie Scheepen, van de Werff der OOSTINDISCHE COMPAGNIE te AMSTERDAM, Op den 2d July 1783, 's Namiddags tusschen 2 en 3 Uuren; te weeten DE MEERMIN, DE BATAVIER, en DOGGERSBANK. Onder het Bestier van DIRK VAN HAAREST, Scheeps Bouwmeester der gemelde Compagnie; van welke Scheepen de Spanten zyn opgerecht, den 2d January, 5 February en 20 dito van 't zelfde Jaar.
Les Trois Navires de la COMPAGNIE des INDES ORIENTALE S, LA SIRENE, LE BATAVE, & LE DOGGERSBANK, lancés à l'Eau à AMSTERDAM, le 2 Juillet 1783, entre 2 et 3 heures après Midi; Sous la Direction de DIRK VAN HAAREST, Maître Constructeur de la dite Compagnie; ne furent Commencés que le 2 Janvier, 5 & 20 Fevrier de la même Année.

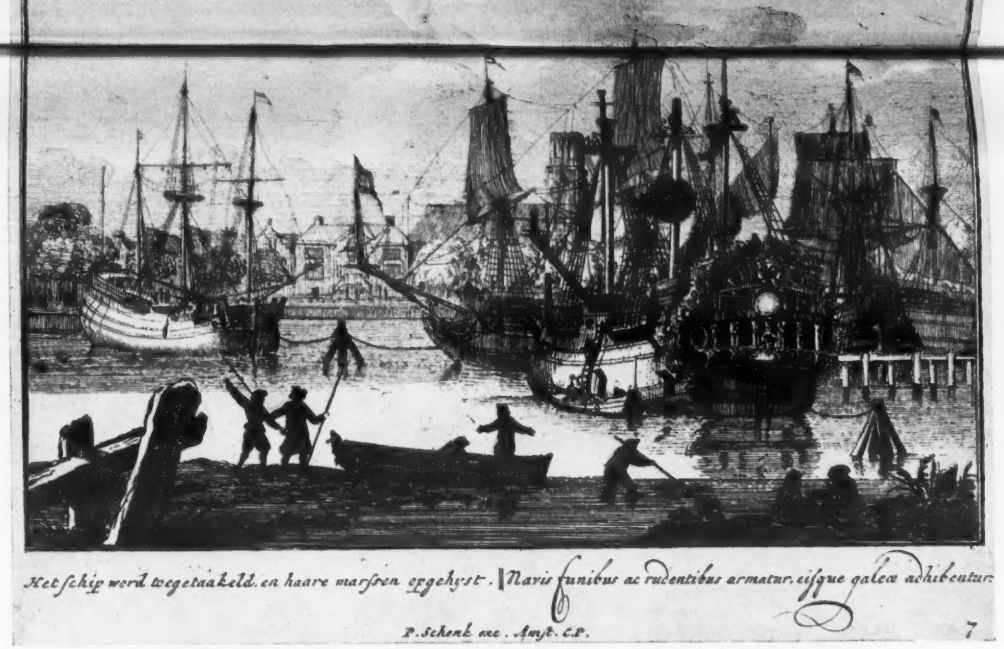
LAUNCH OF THREE VESSELS FOR THE EAST INDIA COMPANY AT OOSTENBURG



SHIPS EARLY IN THE FIRST HALF OF XIX. CENTURY



THE ROYAL FACTORY OF STEAM AND OTHER ENGINES


Het schip word wegetaakeld, en haare marsen opgehyst. | Navis funibus ac rudentibus armatur, ejsque galeæ adhibentur
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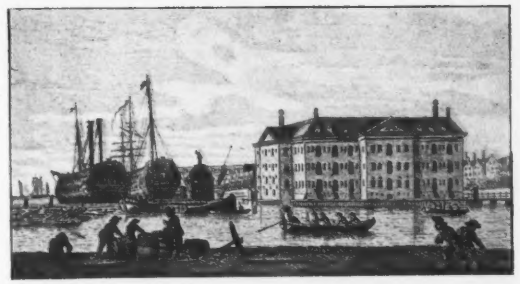
7

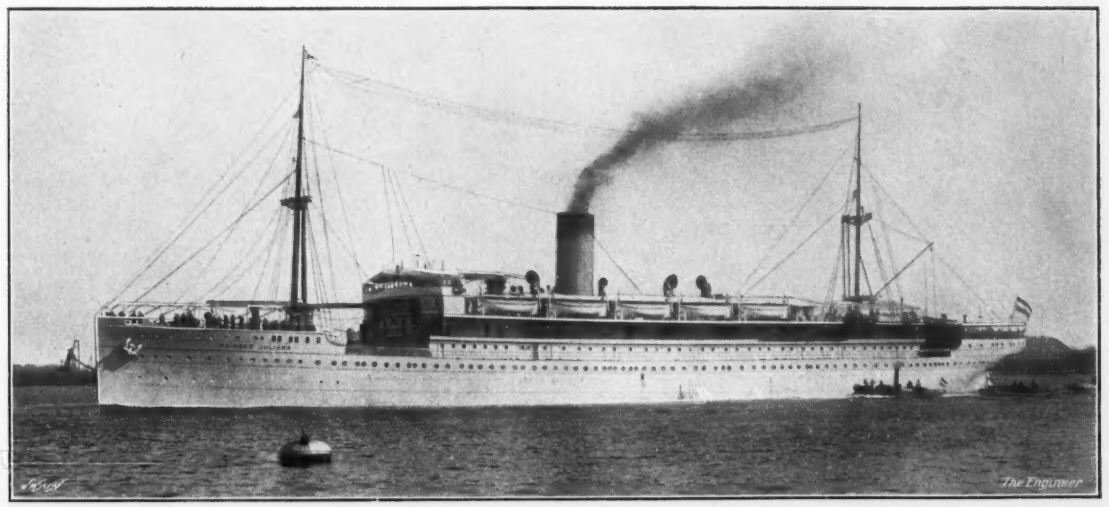
SHIPBUILDING IN AMSTERDAM IN XVII. CENTURY

EAST INDIA COMPANY'S WAREHOUSE



THE ADMIRALTY WHARF AMSTERDAM, 1660

THE NETHERLAND SHIPBUILDING COMPANY, MAY, 1910



T.S.S. PRINSES JULIANA

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JAN 12 1911

The Engineer.

Registered as a Newspaper.

OFFICE FOR ADVERTISEMENTS AND PUBLICATION, 33, NORFOLK STREET, STRAND, W.C.

VOL. CX.—No. 2870] LONDON: FRIDAY EVENING, DECEMBER 30, 1910 [PRICE SIXPENCE

India-office, Whitehall,
28th December, 1910.

The Secretary of State for India in Council is prepared to receive TENDERS from such persons as may be willing to SUPPLY:—

WOODWORKING MACHINERY.

The conditions of contract may be obtained on application to the Director-General of Stores, India-office, Whitehall, S.W., and Tenders are to be delivered at that office by Two o'clock p.m. on Tuesday, the 24th January, 1911, after which time no Tender will be received.

W. G. BUTLER,
Director-General of Stores.
909

Five Assistant Engineers REQUIRED for the Public Works Department of Southern Nigeria for two tours each of twelve months' residential service, with possible extension. Age between 25 and 40, preferably unmarried. Strict medical examination and vaccination if necessary.

Salary £300 a year, rising to £400 by annual increments of £20. Free single quarters provided at established stations. Free first-class passage out and home again on satisfactory termination of engagement. Half salary on voyage out, full salary from date of arrival in the Colony. Two months' leave on full pay after twelve months' tour, increased to four months if returning to the Colony, with full pay during voyage or voyages and free passages.

Candidates should have served their articles with a member or an associate member of the Institute of Civil Engineers, or be possessed of a diploma from some recognised engineers' college, or have been engaged since completion of their articles on public works in a British Colony. They should be capable of designing and carrying out buildings, bridges, and other structures, of taking out priced bills of quantities and preparing detailed estimates, and should have a knowledge of book-keeping and accounting; they should be competent to execute surveys, and take sections and lay out and construct roads, and be familiar with the use of surveying instruments, including theodolite, the dumpy level, the prismatic compass, and the box sextant; they should have some knowledge of dock and harbour work, and of sanitary and water engineering. Preference will be given to candidates who have served their articles with a municipal or county engineer, or who have been or are attached to the Special Reserve, Royal Engineers, and have, since completing their articles, had experience abroad, preferably in a British Colony. Candidates must be of British parentage.

Application by letter (no special form required), stating age, whether married or single, giving full particulars of experience, accompanied by copies of testimonials (not originals), with names and addresses of referees of whom enquiries can be made as to capabilities and character, should be sent at once to the CROWN AGENTS for the COLONIES, 4, Whitehall-gardens, London, S.W.

Quote M. 4532 on left-hand top corner of application. This advertisement contains all the information available concerning the appointment. 910

Two Mechanical Engineers REQUIRED for the Public Works Department of Southern Nigeria for two tours each of 12 months' residential service, with possible extension. Age between 25 and 40, preferably unmarried. Strict medical examination and vaccination if necessary.

Salary £300 a year, rising to £350 by annual increments of £10. Free single quarters provided at established stations. Free second-class passage out and home again on satisfactory termination of engagement. Half salary on voyage out, full salary from date of arrival in the Colony. Two months' leave on full pay after 12 months' tour, increased to four months if returning to the Colony, with full pay during voyage or voyages and free passages.

Candidates must be duly qualified Mechanical Engineers, and have served articles of apprenticeship for not less than three years with an engineering firm in general practice and of good standing. Should be familiar with various kinds of stationary and portable engines, steam and internal combustion, and capable of carrying out repairs to same, and must possess a knowledge of the treatment, care, and repair of land boilers of various types.

Preference will be given to those who have had experience in the erection of structural ironwork, bridges, build ngs, wharves, &c., and have exercised their calling abroad. Candidates must be of British parentage.

Application by letter (no special form required), stating age, whether married or single, giving full particulars of experience, accompanied by copies of testimonials (not originals), with names and addresses of referees of whom enquiries can be made as to capabilities and character, should be sent at once to the CROWN AGENTS for the COLONIES, Whitehall-gardens, London, S.W.

Quote M/4529/38 on left-hand top corner of application. This advertisement contains all the information available concerning the appointment. 913

In the High Court of Justice,
Chancery Division.
Mr. Just ce Parker. No. 1987 of 1910.
In the Matter of W. R. RENSHAW and COMPANY, Ltd. between
BARWELL and OTHERS, Plaintiffs,
and
W. R. RENSHAW and CO., Ltd., and OTHERS, Defe dants
Re W. R. RENSHAW and CO., Ltd, Phœnix Engineering Works, Stoke-on-Trent.

Offers are Invited for this Old- ESTABLISHED BUSINESS as a GOING CONCERN. The company are manufacturers of rolling stock of all types, mining machinery, dredgers, colliery plant, and general engineering constructional work, and are on the Government list, and contract for the leading railways in Great Britain and abroad.

Further particulars may be obtained of the RECEIVER, Mr. A. O. Miles, Chartered Accountant, of the firm of Josolyne Miles and Co., 28, King-street, Cheapside, London, E.C. 908

Nuneaton.

IMPORTANT JUNCTION ON
LONDON AND NORTH-WESTERN MAIN LINE AND MIDLAND RAILWAY.

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of all kinds. Canal and Railway facilities. Close to Collieries. Power, Electric and Gas, cheap. Abundant water. Labour plentiful. Prices reasonable. Gifts of certain Sites for Factories are offered.

FACTORIES CAN BE BUILT TO SUIT TENANTS AND LET ON REASONABLE RENTS.

For particulars apply:
The SECRETARY,
DEVELOPMENT COMMITTEE,
NUNEATON. 630

County Borough of West Ham. APPLICATIONS are invited for the following APPOINTMENT on the TEACHING STAFF of the Municipal Technical Institute:—

ASSISTANT LECTURER in ENGINEERING (£150-£200 per annum).

Full particulars can be obtained by sending a fully addressed foolscap envelope to the Principal, Municipal Technical Institute, Romford-road, West Ham, E., before January 21st, 1911.

By order of the Council,
FRED. E. HILLEARY,
Town Clerk.
Town Hall,
West Ham, E.,
21st December, 1910. 877

Aspatria Urban District Council. The Council invite Engineers to submit PLANS and ESTIMATES of a SCHEME of SEWERAGE and SEWAGE DISPOSAL for their District. Applicants to state inclusive terms upon which they will undertake the work.

The different Schemes will be submitted to a competent Engineer to adjudicate upon, and canvassing the members, either directly or indirectly, will disqualify.

The Surveyor will give particulars required, and plans and estimates must be delivered to the undersigned on or before the 10th day of June next.

Dated this 13th day of December, 1910.
F. RICHARDSON,
Clerk to the Council.
Aspatria, Cumberland. 824

Cadder Parish Council.—Public HALLS, MUIRHEAD, CHRYSTON.
(RAILWAY STATION, GARNKIRK.)

The Halls Committee invite TENDERS for the PURCHASE, including removal, of a "BON-ACCORD" ACETYLENE GAS GENERATOR at the above Halls.

The generator is in fairly good condition, and has a charge capacity of about 56 lb. The diameter of the water tank is about 5ft., and of the gas tank about 2ft.

The generator may be seen on application to the Hallkeeper at the Halls.

Tenders, marked "Gas Generator," are to be lodged with the undersigned on or before Tuesday, 10th January proximo.

The highest or any Tender may not be accepted.
JAMES M'LELLAND,
Clerk.
Bishopbriggs, Glasgow,
26th December, 1910. 891

Great Northern Railway COMPANY (IRELAND).

The Great Northern Railway Company (Ireland) are prepared to receive TENDERS for TWENTY CATTLE WAGONS and EIGHT FIFTEEN-TON BRAKE VANS.

Copies of the specification, drawings, and form of Tender may be obtained on application to the Secretary at Amiens-street Terminus, Dublin, on payment of a fee of Ten Shillings, which will be refunded on the return of the drawings, together with a bonâ fide Tender.

Tenders, under cover, marked "Tender for Wagons," should be delivered to the undersigned not later than 10 a.m. on Monday, the 23rd January, 1911.

The Directors do not bind themselves to accept the lowest or any Tender.

T. MORRISON,
Secretary.
Secretary's Office,
Amiens-street Terminus,
Dublin, 23rd December, 1910. 889

Leeds Corporation Waterworks. TO CONTRACTORS.

The Waterworks Committee of the Leeds City Council invite TENDERS for the CONSTRUCTION of an EXTENSION to BRAMLEY SERVICE RESERVOIR, Leeds, together with roads, drains, sewers, and other works in connection therewith.

Plans may be seen, and forms of Tender, conditions of contract, specification and quantities can be obtained, on or after the 24th day of December, 1910, on application to Mr. C. G. Henzell, Waterworks Engineer, Leeds, on payment of £1, which will be returned on receipt of a bonâ fide Tender.

Arrangements for viewing the site of the works may be made by communicating with the Waterworks Engineer, Leeds.

Tenders, endorsed "Tender for Bramley Service Reservoir Extension," must be addressed to the Chairman of the Waterworks Committee, and delivered in a sealed cover at the Town Clerk's Office, Town Hall, Leeds, not later than 10 a.m. on the 20th January, 1911.

The Committee do not bind themselves to accept the lowest or any Tender.

Waterworks Engineer's Office,
Leeds,
19th December, 1910. 854

Stockport Corporation Water- WORKS.
KINDER RESERVOIR.
CAST IRON PIPES, &c.

The Corporation invite TENDERS for the SUPPLY of about 400 TONS of CAST IRON PIPES and SPECIAL CASTINGS, 27in. or less in diameter.

Drawings can be seen, and copies of the specification, schedule, and form of Tender may be obtained, on and after the 29th December, 1910, at the offices of Messrs G. H. Hill and Sons, Civil Engineers, Albert Chambers, Albert-square, Manchester, and 3, Victoria street, Westminster, upon receipt of cheque for One Guinea. This sum will, after the Corporation shall have come to a decision upon the Tenders, but not before, be returned to the tenderer, provided that he shall have sent in a bonâ fide Tender, and shall not have withdrawn the same, and shall have returned the documents lent to him for the purpose of making up his Tender.

Sealed Tenders, endorsed "Tender for Cast Iron Pipes, Kinder Reservoir, Contract No. 6," and addressed to the Chairman of the Waterworks Committee, must be forwarded to the Town Clerk, Town Hall, Stockport, on or before Friday, the 13th January, 1911.

The Corporation do not bind themselves to accept the lowest or any Tender.

ROBERT HYDE,
Town Clerk.
December 20th, 1910. 887

Swansea Harbour Trust.—The Trustees invite OFFERS for the following PLANT:—

One Compound Surface-condensing Double-crank MARINE ENGINE, cylinders 18in. and 30in., stroke 24in., steam pressure 120 lb.

140 K.W. GENERATOR,

500 r.p.m., 2000 volts, 100 periods, single-phase, complete with exciter, field regulator, slide rails, &c.

One Robey ENGINE, 120 lb. pressure, cylinders 14in. and 25½in., stroke 33in.

150 K.W. GENERATOR,

375 r.p.m., 2000 volts, 100 periods, single-phase, complete with exciter, field regulator, slide rails, &c.

Apply—
WILLIAM LAW,
417 General Manager.

TO MAKERS OF SHIPYARD FURNACES.

Tenders are Required for the DESIGN, SUPPLY and ERECTION of a COMBINED PLATE and ANGLE FURNACE, suitable for Intermittent Work in a large Ship Repairing Yard.

Full particulars and prices should be addressed to SMITH'S DOCK CO., Ltd., North Shields. 839

Wanted, as a Works Manager, for a small Works in the Midlands, a MAN who has had good general experience in office routine, in the management of men, and in carrying out instructions. One who has had experience in brickworks or similar manufacture might suit. Ability to handle men is required rather than technical knowledge. The salary paid will not exceed £3.—State salary, age, experience, whether married or single, when at liberty, to 870, Engineer Office, 33, Norfolk-street, Strand, W.C. 870 A

Wanted Immediately, Young ENGINEER having served his apprenticeship for Modern London Engineering Works, to Train to become part of Staff in the Production and Manipulation of Bleriot and Farman-type Aeroplanes. Splendid opening with good future prospects for an ambitious scientifically inclined person to become expert authority in Aeronautical Engineering. Commencing salary £200. Investment required £50 to £100.—Address full particulars, P48, Engineer Office, 33, Norfolk-street, Strand, W.C. P48 A

Wanted, Engineer, About 30, to Take Charge of large Spinning and Weaving Mill. Must have good shop experience, and accustomed to the control of men.—Write, giving full particulars of experience, copies of testimonials, and salary expected, also stating how soon could be at liberty, to 1370, Sell's Advertising Offices, Fleet-street, London. 902 A

Large Iron and Steel Company in England REQUIRE the SERVICES of a MANAGER for a small tube works, with great possibilities of extension. Applicants should have experience of cold drawn boiler tubes, and especially the commercial side of the business.—Applications, which will be treated in strict confidence, should be addressed to 888, Engineer Office, 33, Norfolk-street, Strand, W.C. 888 A

Managing Engineer Wanted for Marine and General Engineering Works in South Europe, employing 4/500 men, thoroughly competent to take entire charge of estimating, designing, and execution of work, including marine, steam, gas and oil engines, mill work, &c.—Address, stating age, experience, salary required, copies of testimonials, and references, to 849, Engineer Office, 33, Norfolk-street, Strand, W.C. 849 A

Young Engineer Required as ASSISTANT in the PATENT DEPARTMENT of large Continental Engineering Firm. Knowledge of German desirable, but not essential.—Reply, stating full particulars and salary required, to MOENUS MACHINE WORKS, Frankfort-on-Main. 893 A

Applications for Appointments. —Specimen of letters continually being received:—"I am very pleased indeed to say that your application so soon brought me a post. I shall certainly ask for your assistance again if necessary, and shall be pleased to recommend you to anyone I know to be in difficulties."—HERBERT GREATOREX, Application Specialist, Beechwood, Matlock. 458 A

Wanted, at Once, by London General Engineering Works, a first-rate all-round practically and technically experienced general DRAUGHTSMAN. Some electrical and air-compressing knowledge an advantage. Follow up inquiries and see own work through. Possibilities to a suitable man. Londoner preferred. Reply in confidence, stating age, if disengaged, salary required, with full particulars of experience. Only those selected for an interview will be replied to.—Address, P45, Engineer Office, 33, Norfolk-street, Strand, W.C. P45 A

Wanted Immediately, at Elec- TRICITY Works, North-East of England, JUNIOR DRAUGHTSMAN for about six months; one with some knowledge of Mains record work and slight knowledge of surveying.—State age and salary to 912, Engineer Office, 33, Norfolk-street, Strand, W.C. 912 A

Wanted Immediately, Rolling STOCK DRAUGHTSMAN, used to Electrical Tramcar and Railway Carriage Work. Must be quick and reliable.—Give full particulars of experience, and state age, salary required, and when at liberty, to Box 400, at Horncastle's, 61, Cheapside, London. 781 A

Draughtsmen Wanted, One As- SISTANT and one Junior, in Works about 12 miles east of London. Must be accustomed to Small Machinery and Jig and Tool Work.

Write, stating age, experience, salary expected, and when at liberty, to P38, Engineer Office, 33, Norfolk-street, Strand, W.C. P39 A

Draughtsman.—Wanted, Smart MAN, accustomed to the design of Direct-acting Steam Pumps, Air Pumps, and general hydraulic work. State age, experience, and wages required.—Address, 905, Engineer Office, 33, Norfolk-street, Strand, W.C. 905 A

Junior Draughtsman Required for Engineering Works in Manchester; one having good general experience preferred.—Address, 897, Engineer Office, 33, Norfolk-street, Strand, W.C. 897 A

Junior Draughtsman Wanted at once, with experience in Gas and Oil Engine Design.—Apply, giving full particulars, including age, experience, and salary required, to PETTERS, Limited, Nautilus Works, Yeovil. P38 A

Screening Plant Draughtsman REQUIRED. State age, experience, and salary required.—Address, 903, Engineer Office, 33, Norfolk-street, Strand, W.C. 903 A

Smart Draughtsman Required by Electric Crane Makers in North of England. Must be quick and reliable, have wide experience in design, and be accurate in getting out working details. State age, experience, and salary required.—Address, 892, Engineer Office, 33, Norfolk-street, Strand, W.C. 892 A

Wanted, Good Foreman Moulder (SAND), for a General Iron Foundry in London.—Apply, with references and salary required, Z., Box 883, Smith's Advertising Agency, 100, Fleet-street, E.C. 901 A

Foreman Wanted to Take Charge of Gypsum Quarry and Calcining Furnaces for white cement, plaster of Paris, &c., in South of France.—State experience and salary required, with references, to E. EVANS, 18, Ropemaker-street, E.C. P46 A

Canvasser Required for Engi- NEERING Journal, London and district.—Write stating age, experience, and terms expected, to Box G. E. C., 52, Gray's Inn-road, W.C. 911 A

First-class Mechanics Required for the Balloon School, Royal Engineers; thoroughly experienced with Petrol Motors; good fitters, and capable of Repairing Mechanical Part of Airships. Commencing pay 38s. 6d. per week, in addition to clothing, quarters, and rations.

Full particulars may be obtained from the SUPERINTENDENT, Balloon Factory, South Farnborough, Hampshire, or any Recruiting Officer. 856

A.M.I.C.E. (32) Desires Ap- POINTMENT, 15 years' practical experience, mechanical and structural engineering, reinforced concrete.—Address, P47, Engineer Office, 33, Norfolk-street, Strand, W.C. P47 B

Manager (30) of Small Limited Company, General Engineering, DESIRES CHANGE, Glasgow or North-East Coast; commercial, technical, practical training.—Address, MANAGER, William Porteous and Co., Glasgow. P40 B

Technical Chemist (32), Several years' experience in the manufacture of acids, high explosives, hydrogen peroxide, &c., erection of plant and control of men, is OPEN for ENGAGEMENT, home or abroad.—Address, P7, Engineer Office, 33, Norfolk-street, Strand, W.C. P7 B

Draughtsman or Assistant MANAGER; 10 years' chief; can overcome mechanical difficulties; first-class general experience; age 36; now disengaged.—Address, P49, Engineer Office, 33 Norfolk-street, Strand, W.C. P49 B

Draughtsman (29), London, or as ASSISTANT to Engineer; 7 years shops; excellent refs.; all-round experience.—Address, P44, Engineer Office, 33, Norfolk-street, Strand, W.C. P44 B

Experienced Draughtsman in General Mechanical Engineering SEEKS temporary or permanent EMPLOYMENT in London; 15 years' workshop experience; English, French, Italian languages.—A. C., 11, Polygon, Old Town, Clapham. P43 B

Situation Wanted as Junior DRAUGHTSMAN.—JAMES WILLIAMS, 48, Cecil-road, Upton Manor, E. P37 B

Clerk (26), with Technical Train- ING, shorthand-typist, correspondent English, German, French, DESIRES ENGAGEMENT in Costing or Correspondence Dept. with Engineers or Patent Agents.—Address, P42, Engineer Office, 33, Norfolk-street, Strand, W.C. P42 B

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SITUATIONS, FOR SALE, &c.

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The Moorit Jointing Co. Re-QUIRE AGENTS for their high-class STEAM and WATER JOINTING MATERIALS in all principal towns in Great Britain and Colonies.—Apply, 2, Norfolk-street, Strand, London, W.C. 569 D

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Enquiries solicited from gentlemen desirous of purchasing partnerships in sound concerns or from firms requiring partners

Active Director Required, with £10,000, in a well-established Engineering Works, Midlands, manufacturing specialities. Incomer must be experienced, and a worker. Good terms to suitable man.—Particulars from ARNOLD and CO., 76, Cannon-street, E.C. 900 c

Wanted, Latest Pattern Heavy 12in. S.S.S. LATHE, for high-speed steel, to take not less than 10ft. between centres.—Weight, price, and delivery to S. RICHARDS and CO., Limited, Shipbuilders and Engineers, Lowestoft. 879 F

Wanted, Two Galloway Type BOILERS; must be in good condition; size about 30ft. by 7ft.; stand 100 lb. pressure.—Reply, W. J. WHITE, 17, Hardwicke-road, Chiswick Park, W. F41 F

Wanted, 250 H.P. Producer Gas PLANT, good second-hand.—Full particulars and price to WILLIAMS and SONS, 73, Queen Victoria-street, London. 914 F

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LOCO. TYPE BOILER, 10 N.H.P., 150 lb. working pressure. 6in. by 18in. THREE-THROW WELL PUMPS.
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75 B.H.P. Crossley Gas Engine, 17½in. cyl., 24in. stroke.

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Two Compound Worthington Duplex Pumps, 14in. and 20in. steam cyls., 12in. water cyls., 10in. stroke.
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7 and 8, Southampton-buildings, Chancery-lane, London, W.C.

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Chartered Patent Agents and Consulting Engineers, 847 H
7 and 8, Southampton-buildings, Chancery-lane, London, W.C.

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Chartered Patent Agents and Consulting Engineers, 7 and 8, Southampton-buildings, Chancery-lane, London, W.C.
893 H

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HAASENSTEIN and VOGLER, A.G.,
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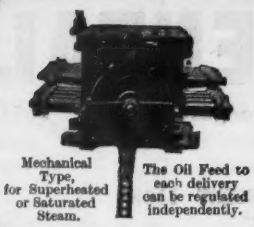
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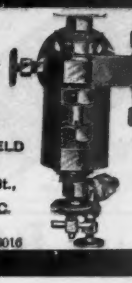
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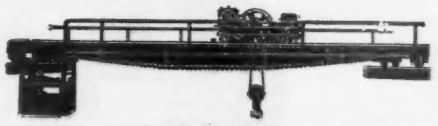

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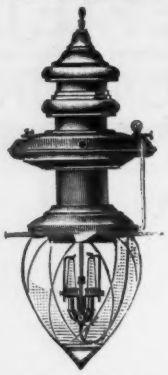

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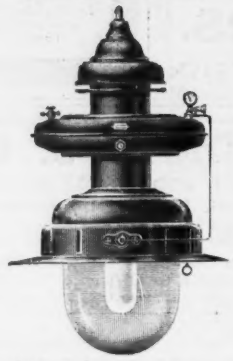

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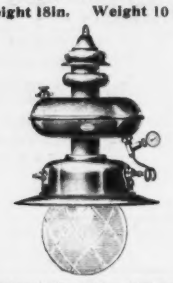

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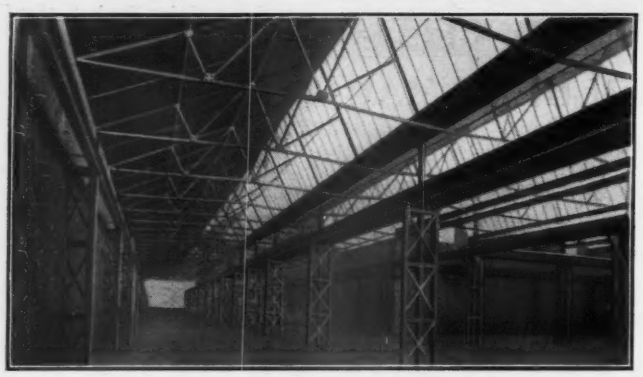

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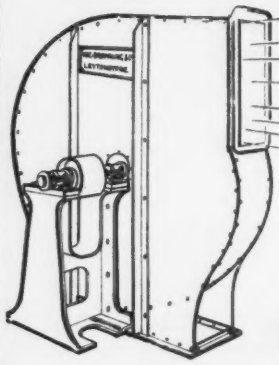

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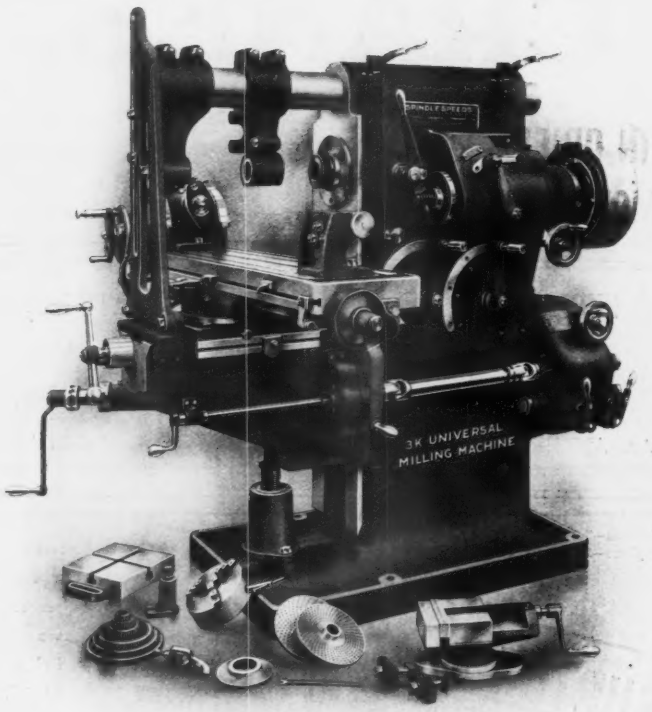

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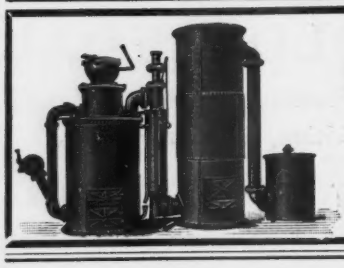

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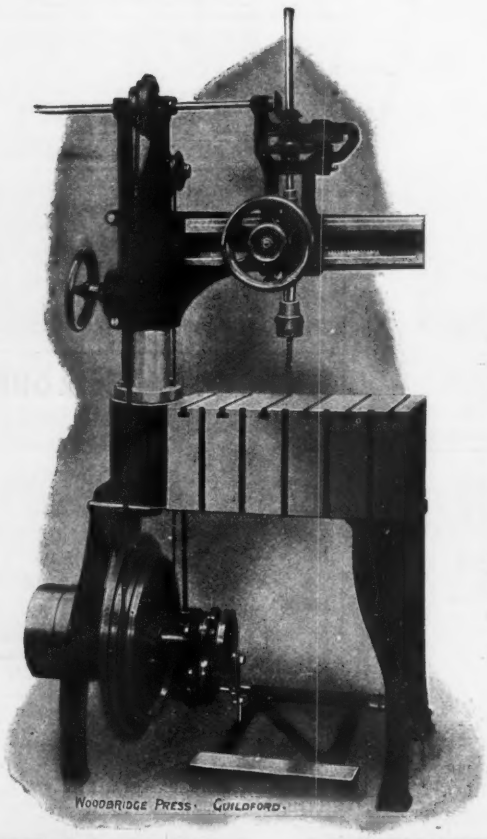

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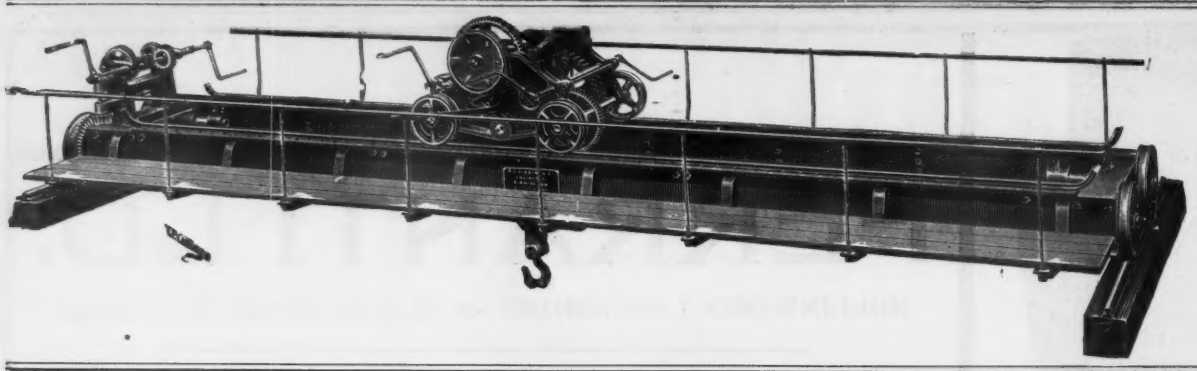

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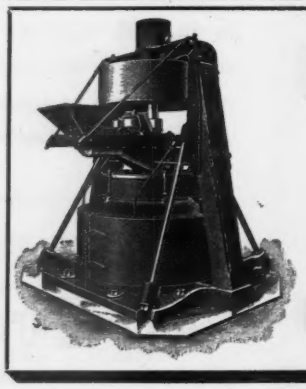

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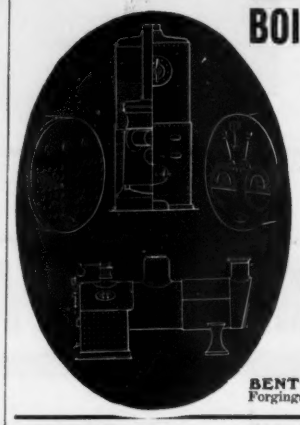
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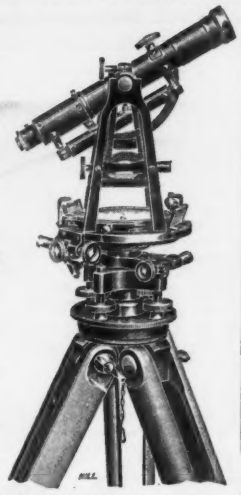

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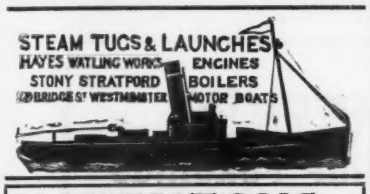

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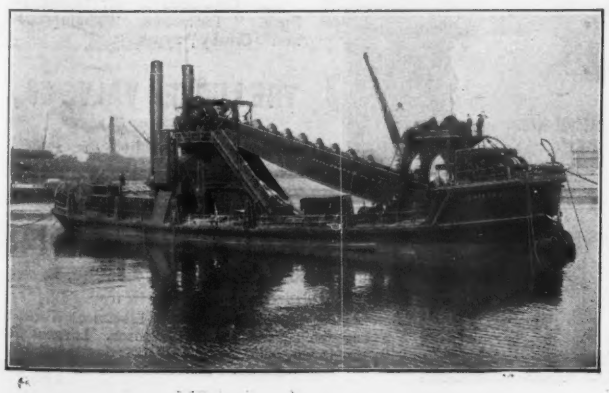

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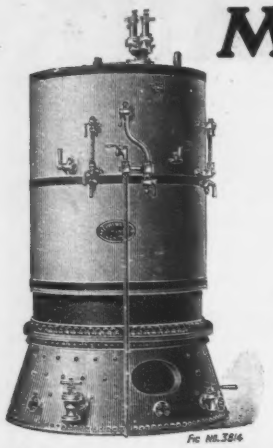

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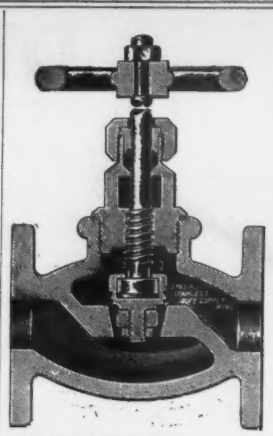

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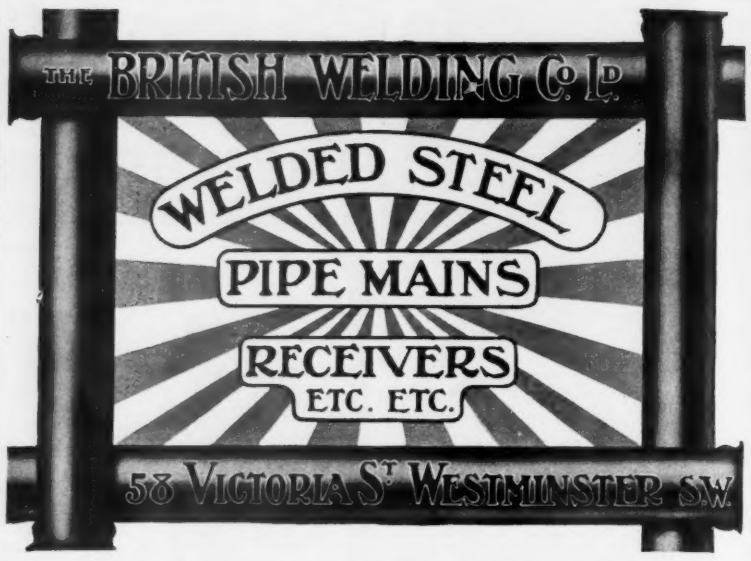

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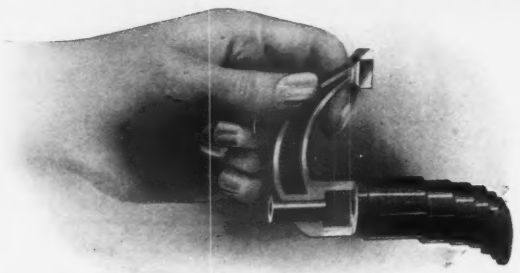

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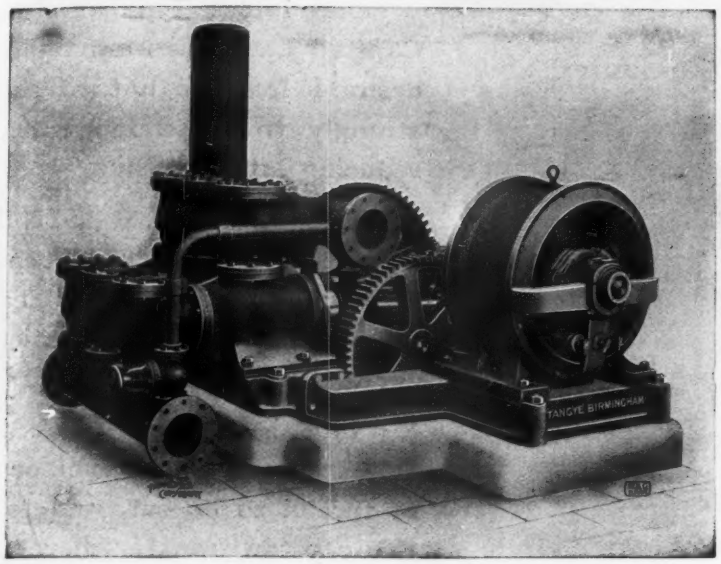

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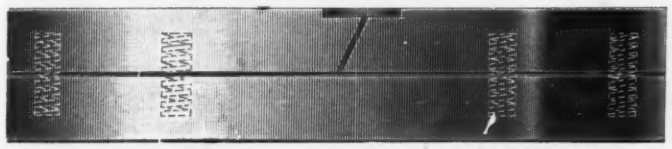

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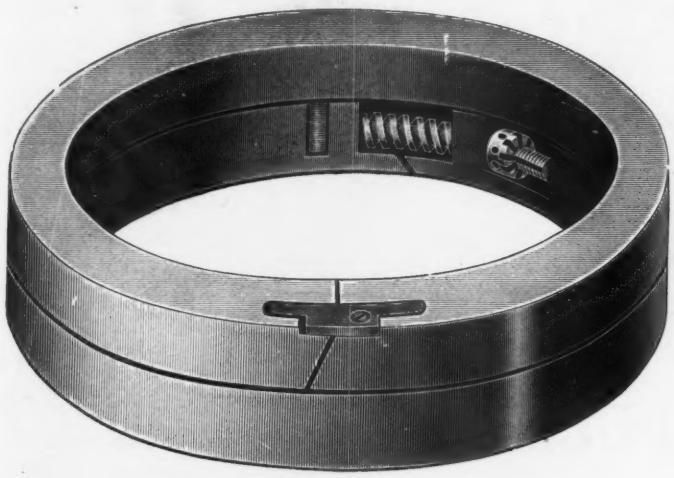

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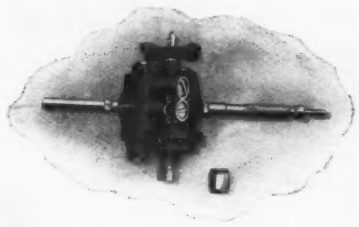

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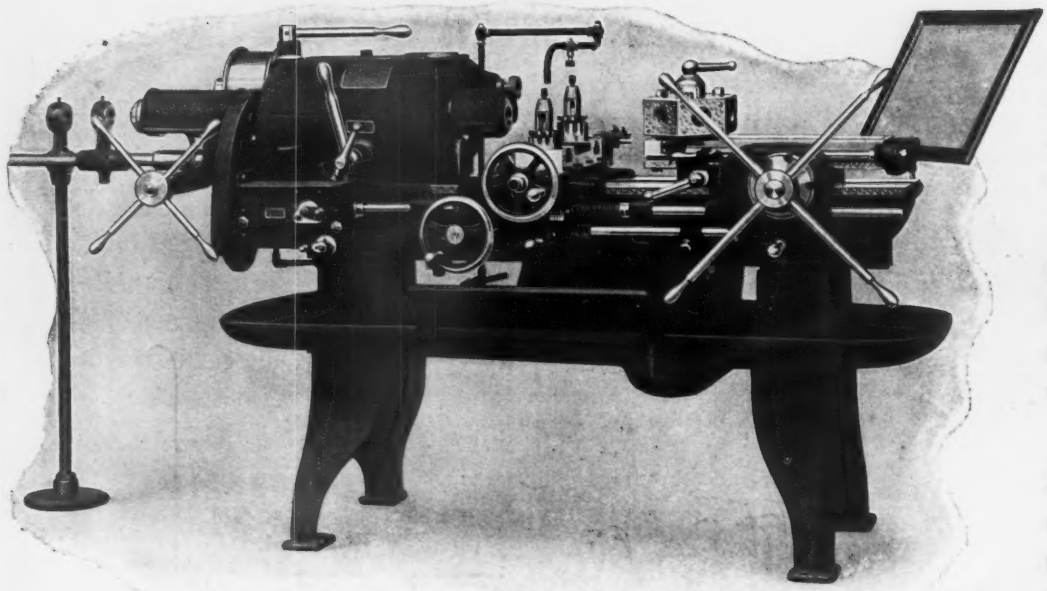

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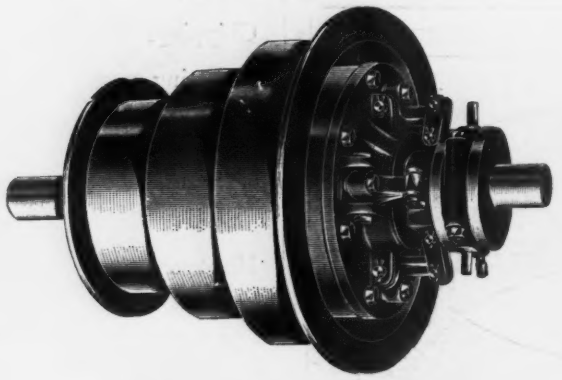

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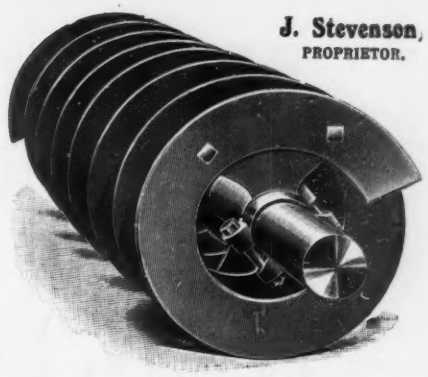

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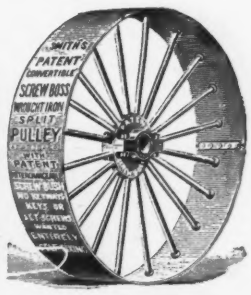

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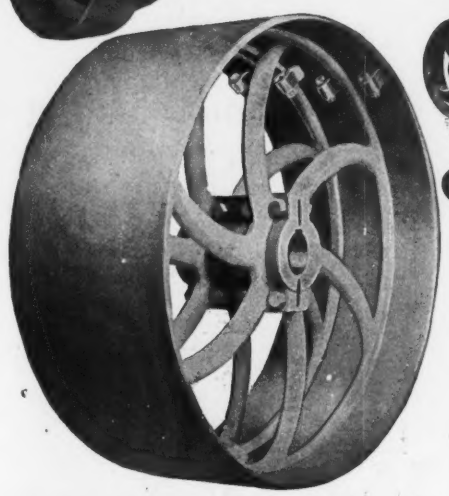

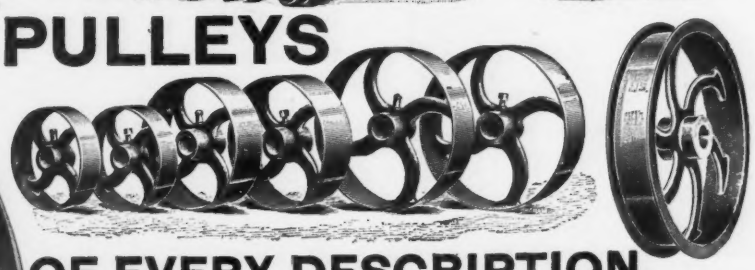

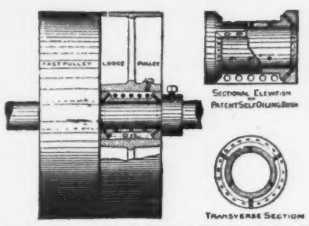

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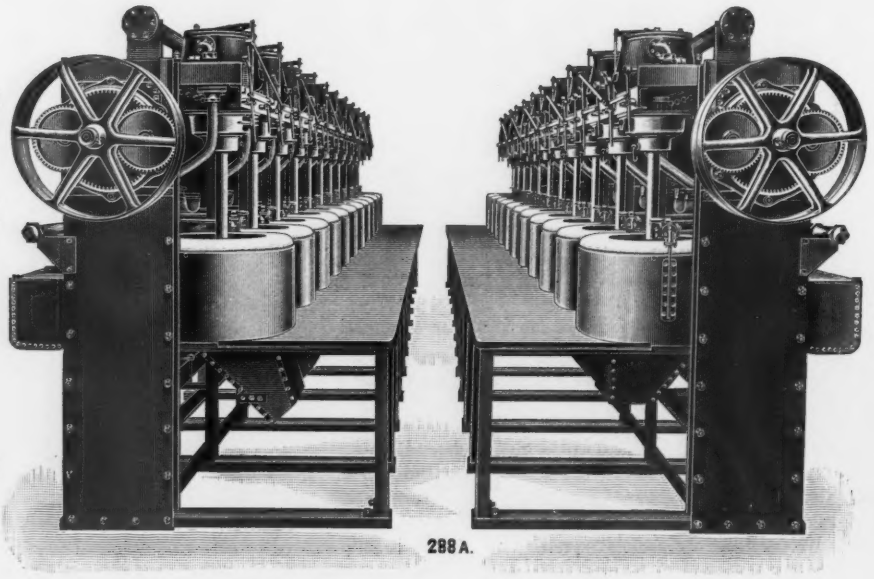

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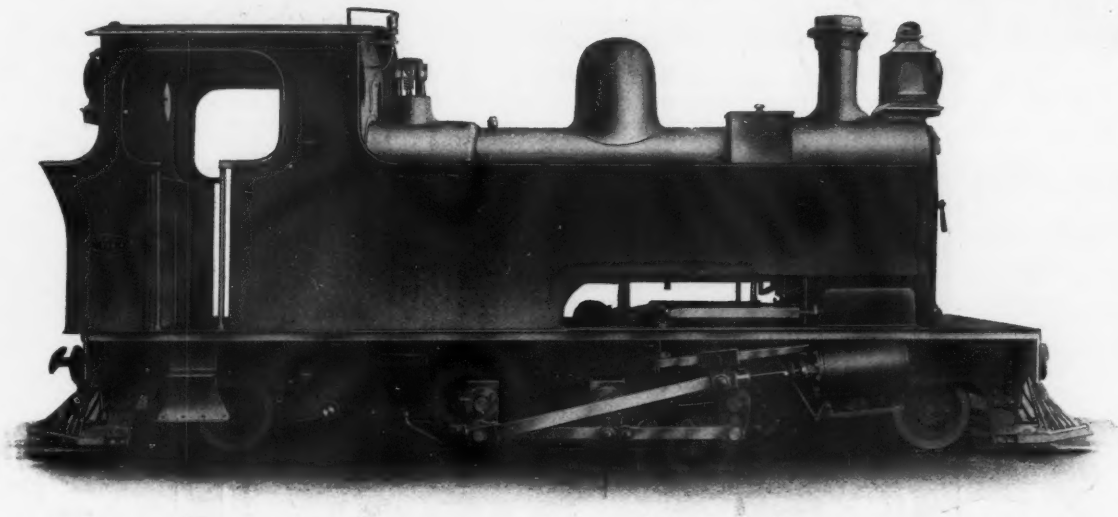

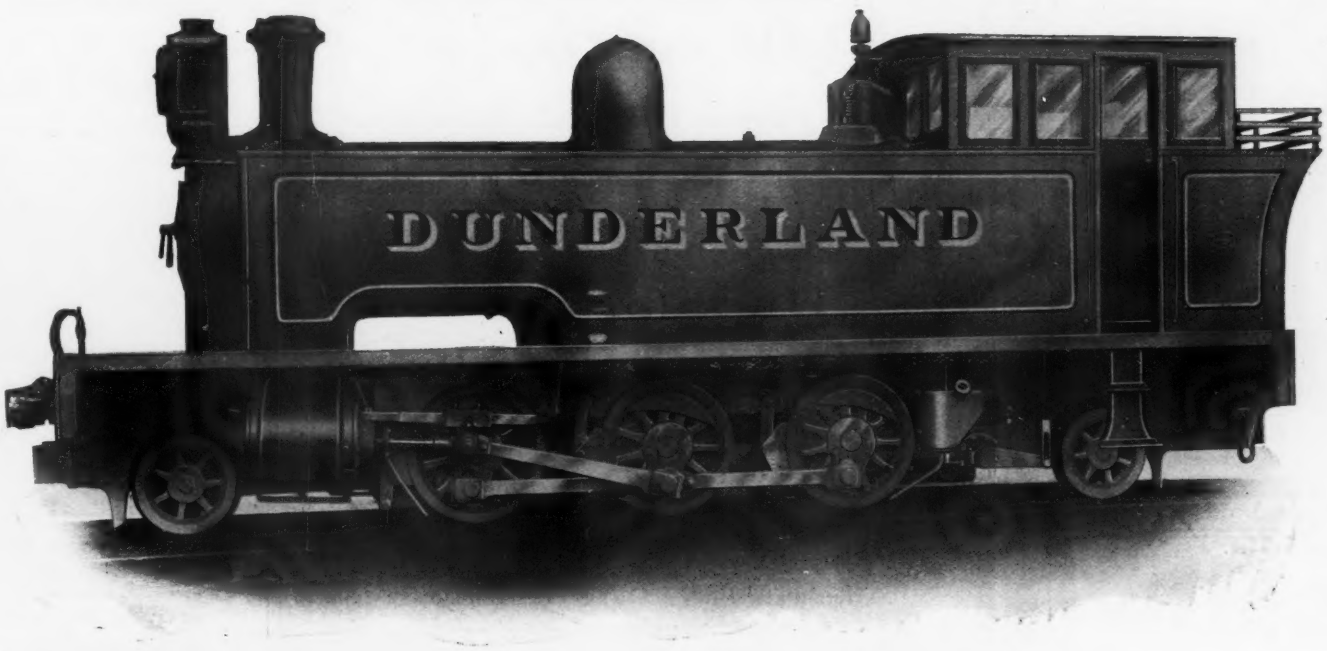

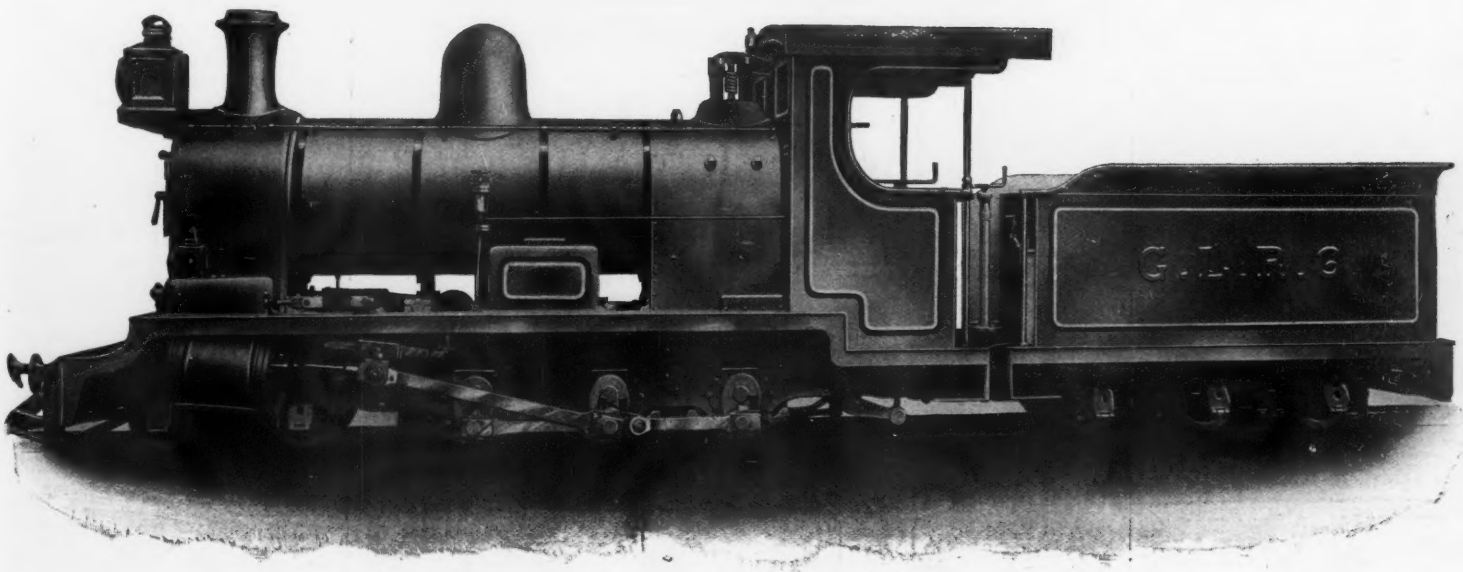

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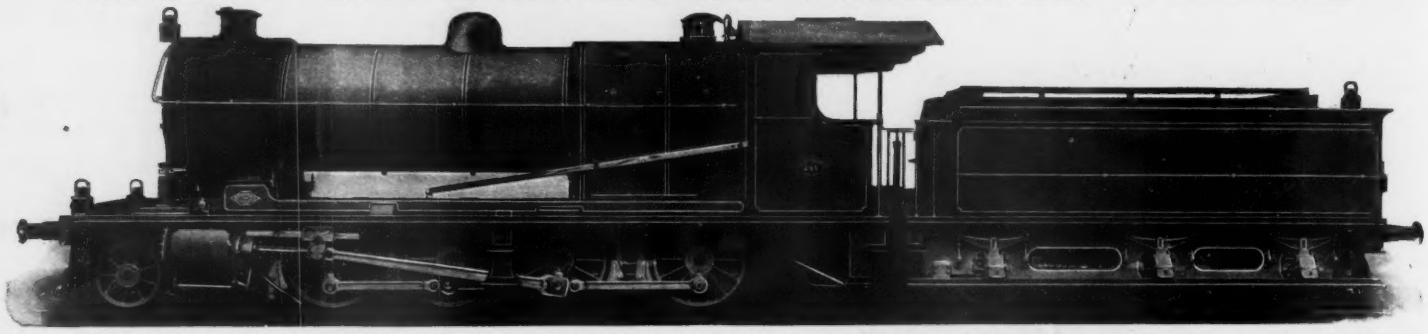

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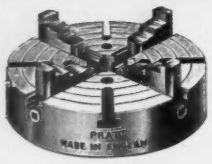

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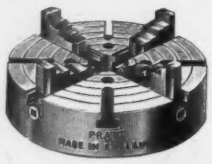

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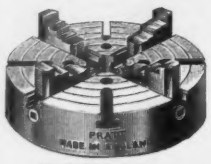

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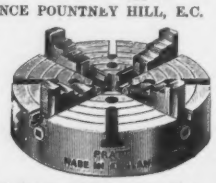

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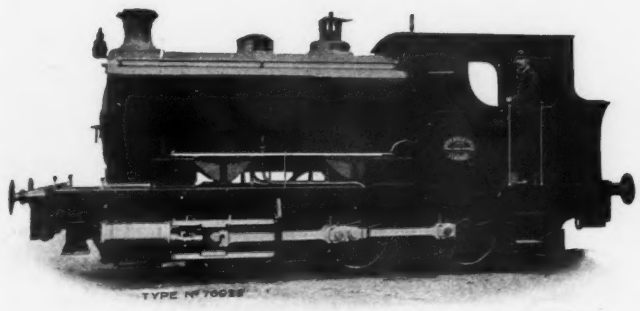

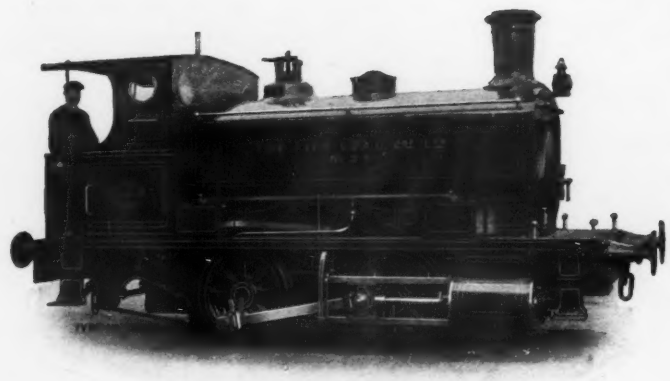

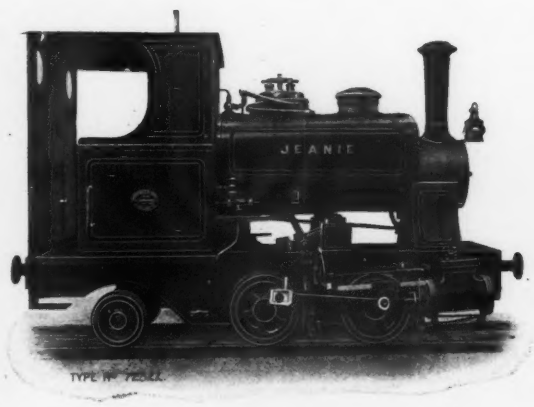

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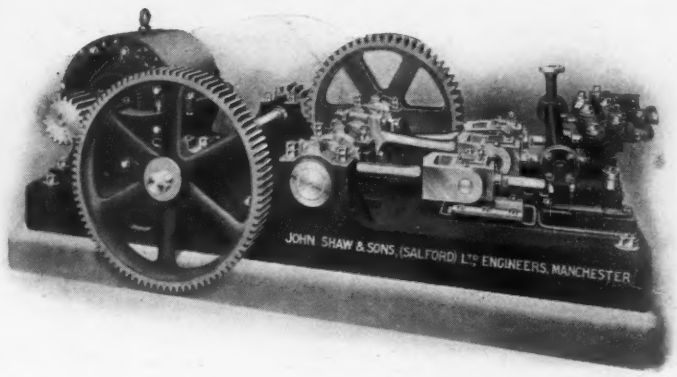

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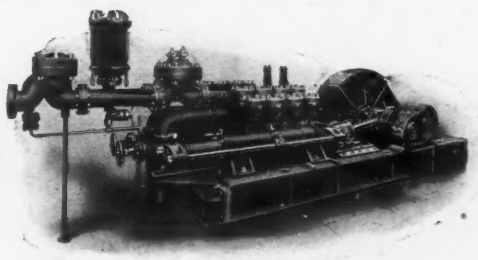

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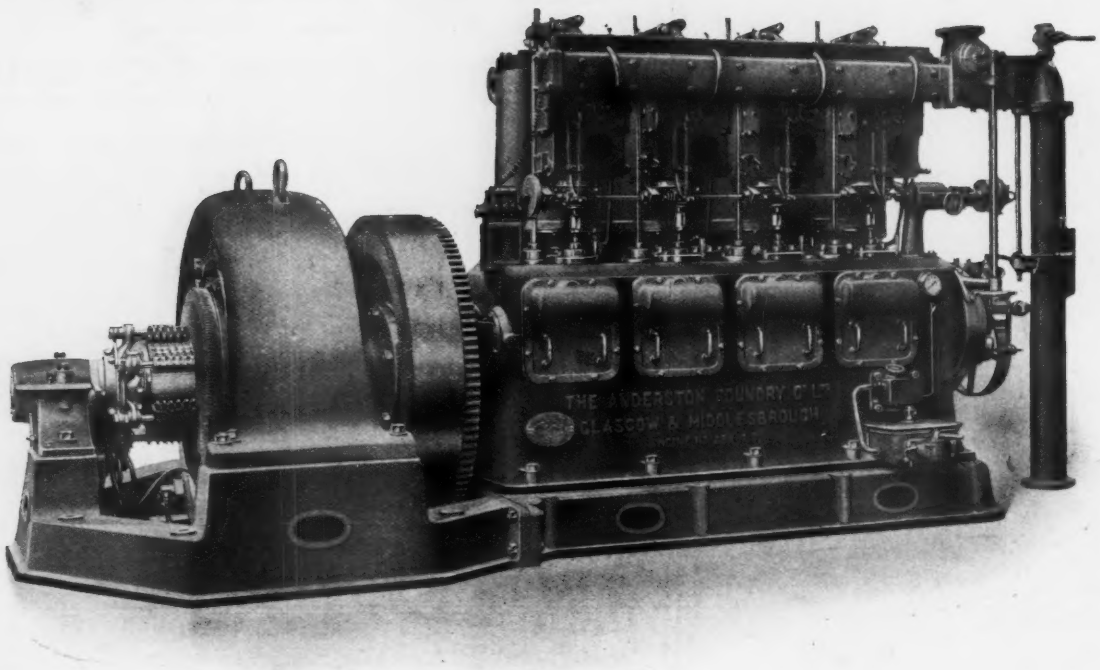

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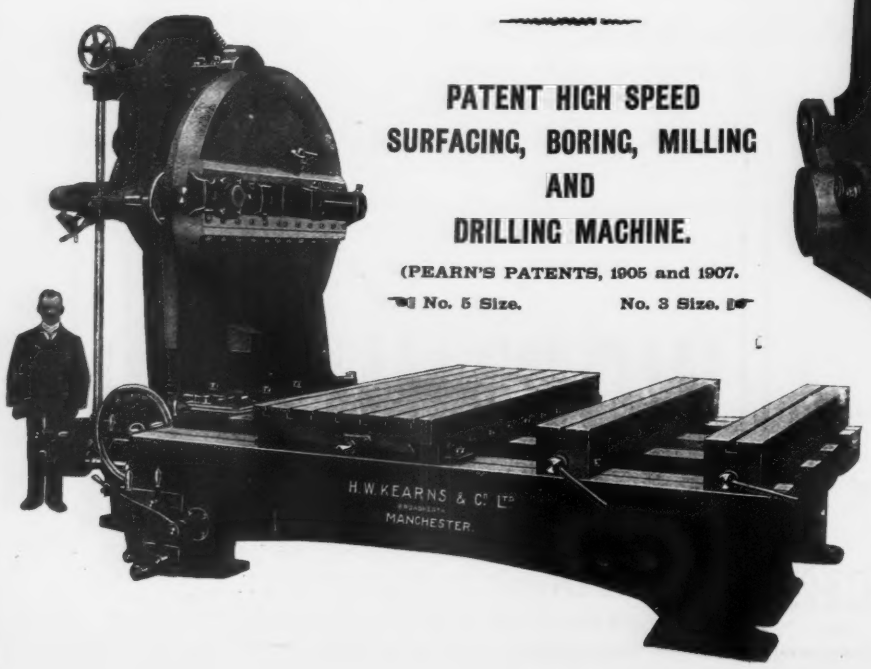

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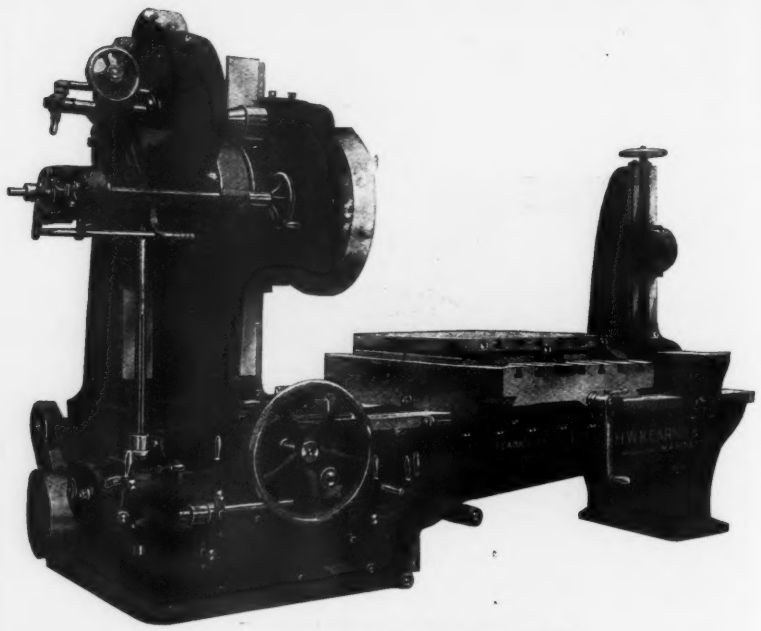

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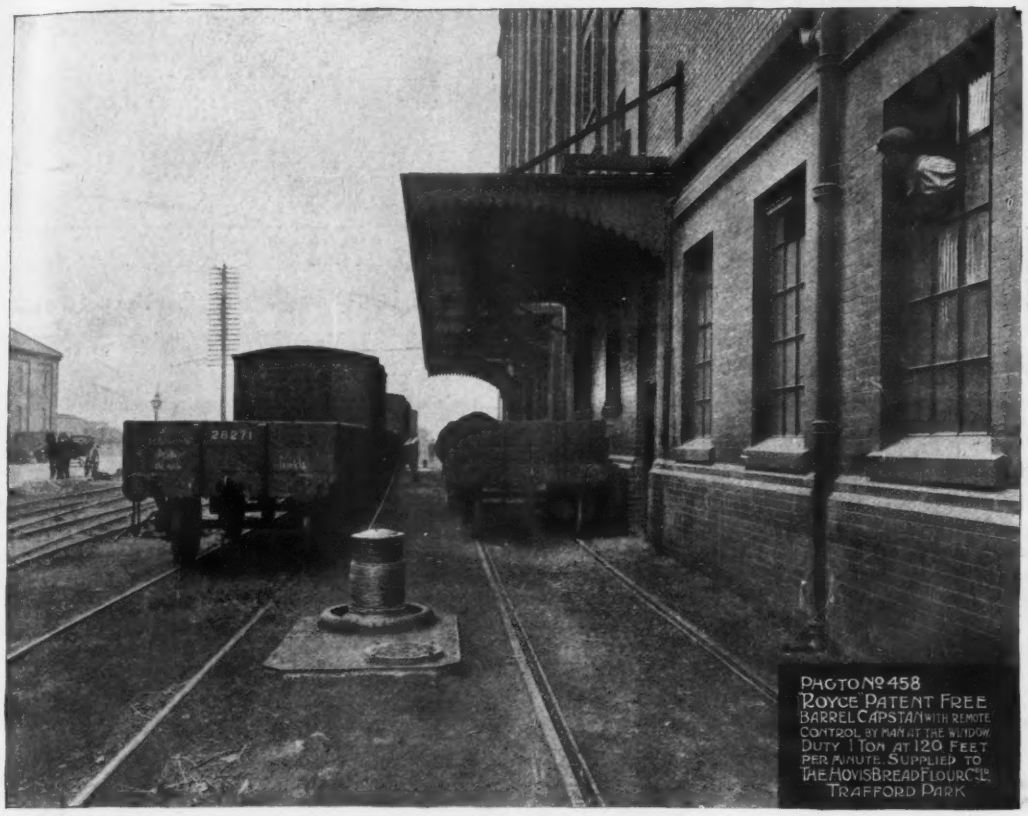
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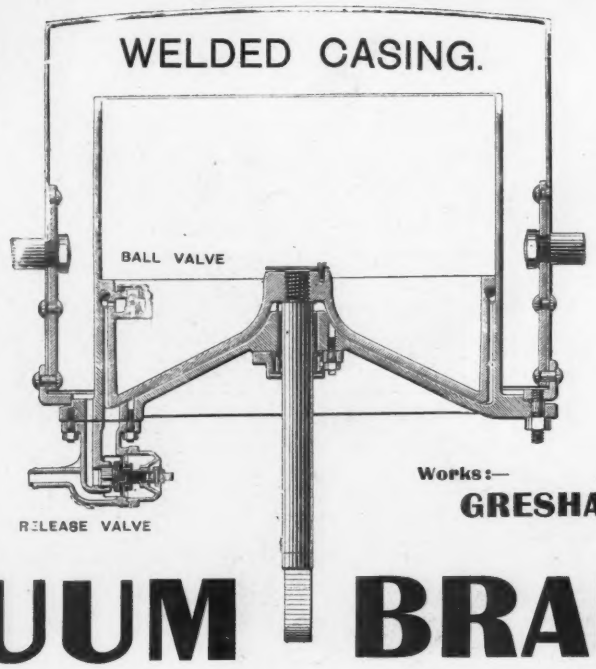

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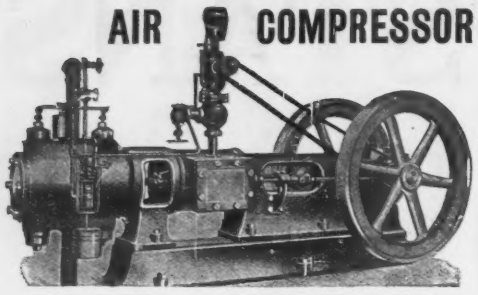

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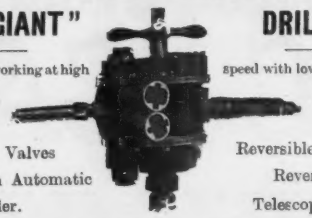

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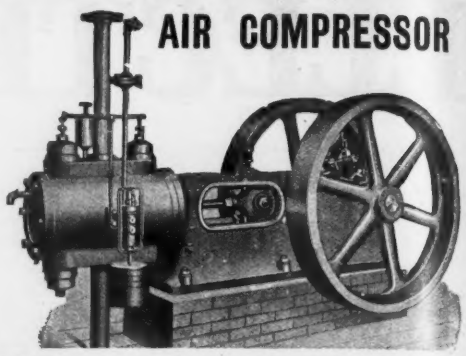

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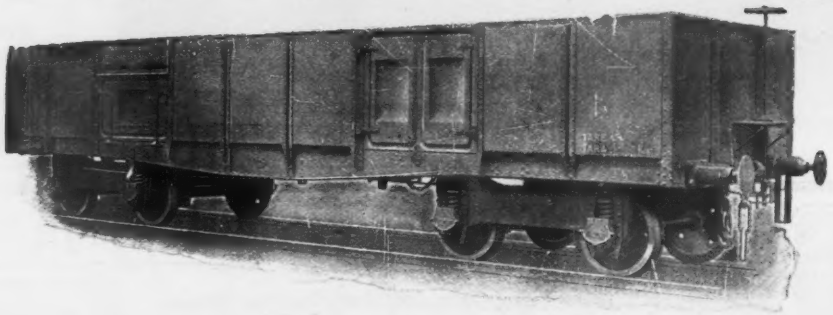

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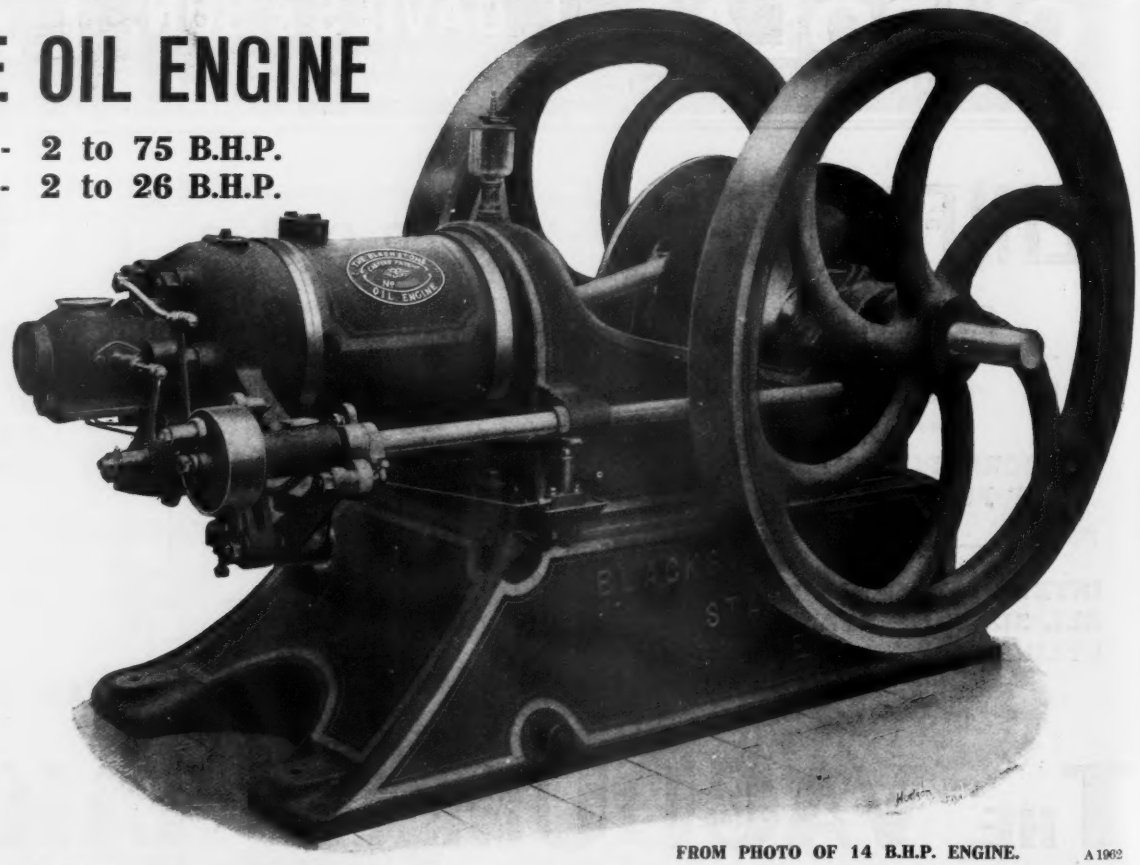

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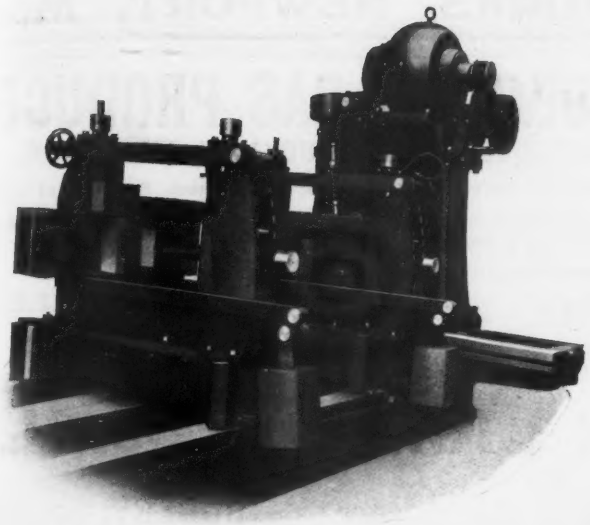

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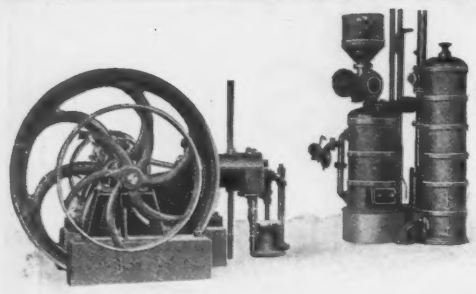

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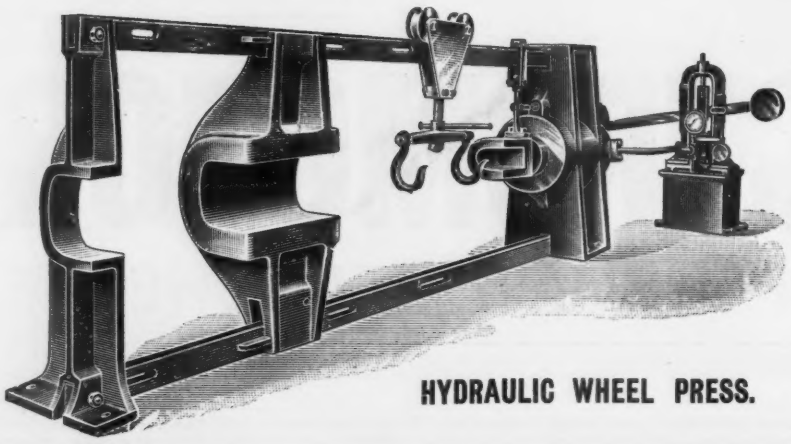

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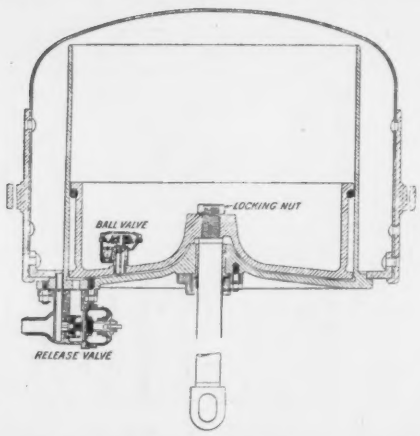

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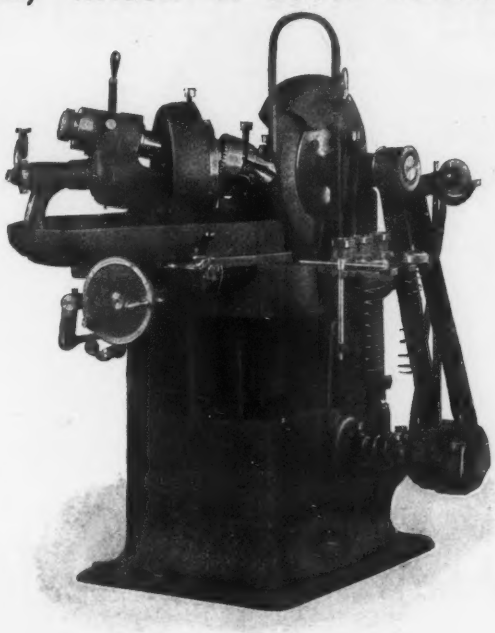

Operator only has to put the drills in and start the feed, which trips automatically upon reaching the desired distance.

OUTPUT OF DRILLS GROUND, 30-40 per hour.

As each lip of the drill is ground successively, there are no errors due to wear of wheel or inaccurate feeding, as is common when one lip only is completed and the entire process repeated on the other.

Will Grind 30-40 Drills per hour.

MADE IN TWO SIZES:

No. 3 for Drills $\frac{3}{8}$in. to $2\frac{1}{8}$in.

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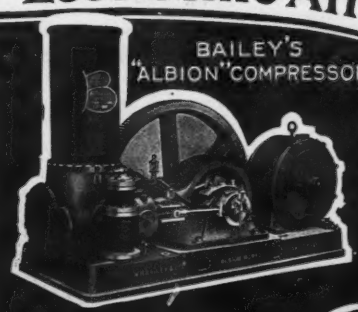
BAILEY'S "ALBION" COMPRESSORS



STEAM, BELT, OR ELECTRIC DRIVEN.

SPEEDS TO 1000 REVS. PER MINUTE !!!

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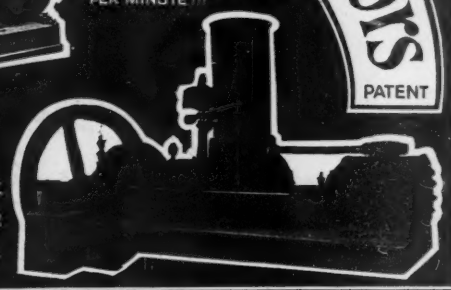

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LEAST DRIVING POWER.
ACCESSIBLE - COMPACT - SILENT.
ONLY ONE VALVE. LOW UPKEEP.
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BAILEY'S "DAVIDSON" STEAM PUMPS.

BAILEY'S "DAVIDSON" PATENT INDEPENDENT FEED AND AIR PUMPS FOR STEAMSHIPS AND WORKS.

FIG 10. "DAVIDSON" STEAM PUMP.

MINE AND HYDRAULIC PUMPS.

WATERWORKS AND WELL PUMPS.

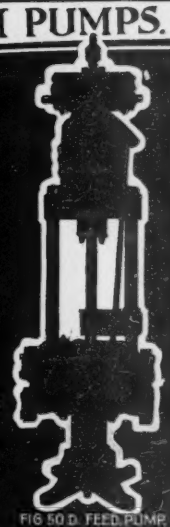

FIG 50 D. FEED PUMP.

STEAM, BELT, ELECTRIC, THREE THROW PUMPS &c.

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Schieren's Duxbak Waterproof Leather Belting

has successfully withstood water in all parts of the world and conditions of dampness that weakened other so-called waterproof beltings.

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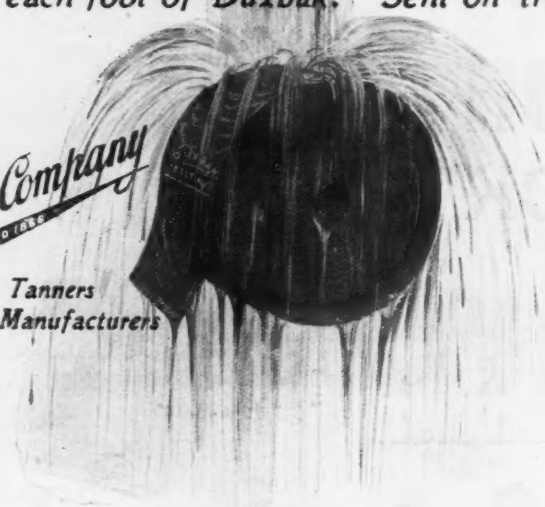

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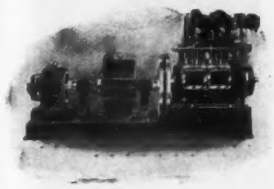
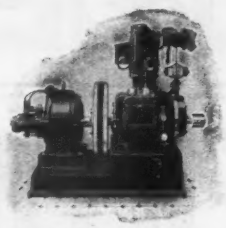
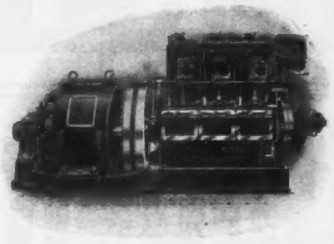


24 Brake Horse-Power.



12 Brake Horse-Power.



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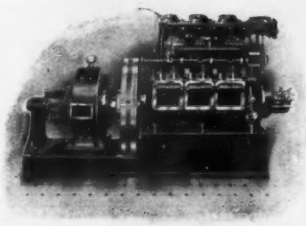
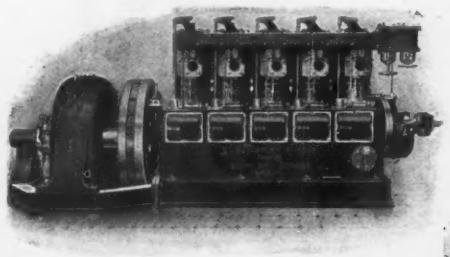
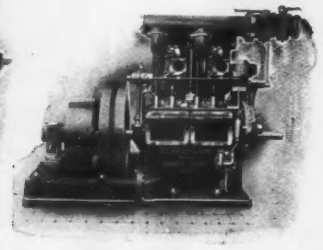


36 Brake Horse-Power.



185 Brake Horse-Power.



50 Brake Horse-Power.

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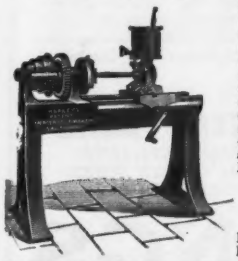
To SCREW BOLT MAKERS

Engineers, Wagon Builders, &c.



This Patent SCREWING MACHINE can be worked either by a BOY or GIRL, and will screw at the rate of from 25 to 30 gross of ¼in. bolts per day of ten hours, or other sizes at proportionate speed. This Machine is also well adapted for Tapping Nuts.

As Supplied to Governments.

Prices and particulars on application to

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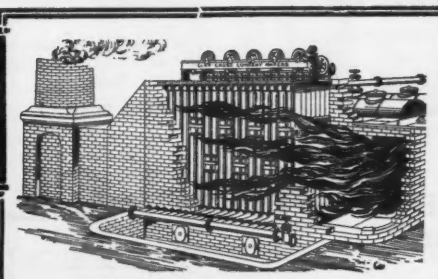
HOLLINWOOD, near MANCHESTER.

THE CLAY CROSS CO. Nr. Chesterfield. ESTABLISHED 1837.



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No. 38	Lamp with 200 c.p. burner, Copper Oil Reservoir, 15 hours' capacity, 19in. high...	5 0 0
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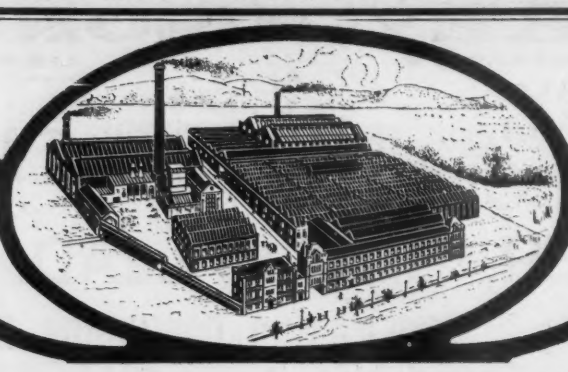

Brussels Exhibition—Grand Prix.
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VALVES ~ BOILER MOUNTINGS

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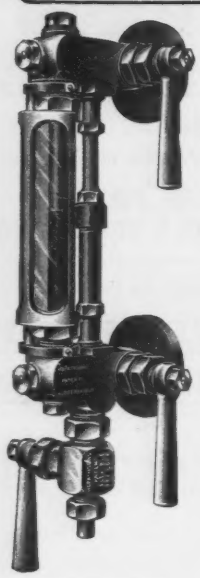
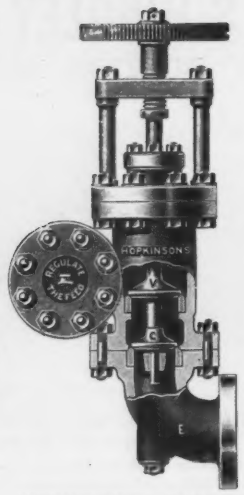


HOPKINSON'S PATENT 'ABSOLUTE' WATER GAUGES.
Fig. 6440.
Automatically shuts off water and steam when the gauge glass bursts. Fitted with Hopkinson's Safety Shields and Patent Safety Plugs.

HOPKINSON'S PATENT "IPSED" DEAD-WEIGHT SAFETY VALVE.
Fig. 10.
With Hopkinson's Platnam Metal Seat with controlled flow and lock-up weights, for high steam only.

HOPKINSON'S PATENT BLOW-OFF VALVE.
Fitted with Hopkinson's Platnam Metal Seats and Discs.
Fig. 2540.



HOPKINSON'S PATENT "ACCESSIBLE" CHECK FEED VALVE.
Fig. 1320.
Check valve can be examined whilst boiler is under steam.

HOPKINSON'S PATENT "TRIAD" JUNCTION VALVE.
Fig. 1000.
Fitted with Hopkinson's Platnam Metal Valve and Seat and Rotate Handle, enabling the valve to be rotated on its seat so as to find a fresh bearing (this ensures fluid tightness and durability).

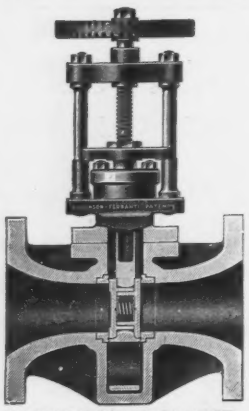
SPECIFY
HOPKINSON'S "PLATNAM" METAL
SUITABLE FOR BAD WATERS AND SUPERHEATED STEAM.

HIGH-CLASS PATENT

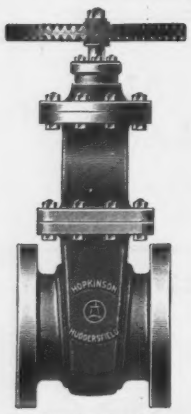
SPECIFY
HOPKINSON'S "PLATNAM" METAL
WHICH DOES NOT DETERIORATE LIKE GUN-METAL AND OTHER ALLOYS WHEN SUBJECT TO HIGH TEMPERATURES.

SAFETY BOILER MOUNTINGS and VALVES

with Seats of
HOPKINSON'S "PLATNAM" METAL.

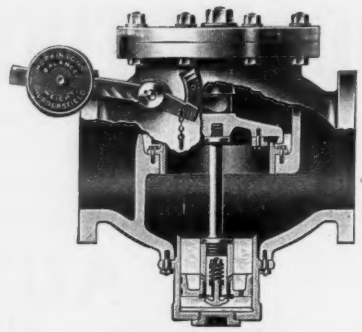


HOPKINSON-FERRANTI PATENT STOP VALVE, for Steam and High-pressure Water Service.
Saves weight, cost, and leakage. Fitted with Hopkinson's Platnam Metal Seats and Discs.



HOPKINSON'S WEDGE SLUICE VALVE.
For Water or Exhaust Steam.
Fig. 2030.

HOPKINSON'S PATENT "MAC" VALVE.
Fitted with renewable valve and seat of Hopkinson's "Platnam" Metal. Flanged and screwed ends. Inside and outside screws.



HOPKINSON'S "SILENT" AUTOMATIC EXHAUST VALVE.
Water sealed.
With combined lever and steadying dash-pot.
Fig. 7050. Q607

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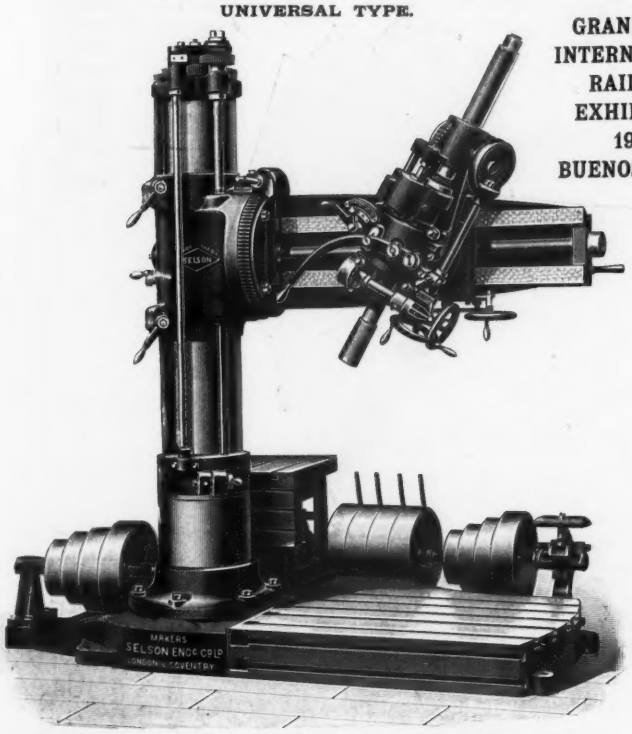
With REVERSING MOTION FOR TAPPING, &c.

Wide range of Speeds. 4 or 6 Positive Feeds, according to size, enabling Reversing Gears to run at high speed. Taps withdrawn 4½ times quicker than tapping speed. FIRST-CLASS WORKMANSHIP THROUGHOUT. Ball Thrust to Spindle. Gearing placed on Spindle. ALL GEARS CUT FROM SOLID BLANKS.

UNIVERSAL TYPE.

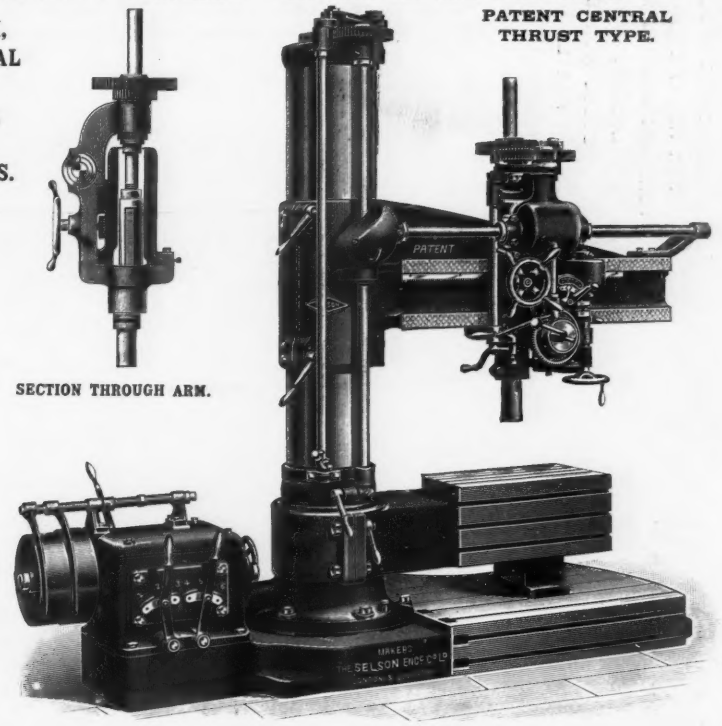


SPECIAL FEATURE. — The driving shaft passes through the fulcrum, and has TWO bearings instead of one only, as in most other designs.

GRAND PRIX, INTERNATIONAL RAILWAY EXHIBITION, 1910, BUENOS AIRES.

SECTION THROUGH ARM.

PATENT CENTRAL THRUST TYPE.



SPECIAL FEATURES.—The carriage is gibbed to arm both on front and underneath, the fron plate carrying top bearing of spindle, whilst the under one forms the lower bearing and takes the central thrust of drill, in line with centre of arm and column.

THE SELSON ENGINEERING CO., Ld.

Incorporating Selig, Sonnenthal and Co., London, and the Selson Machine Tool Works, Coventry. T1216

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'The results far outdistance anything that has ever been previously accomplished with a pumping engine."—Prof. Orr's Report.

TRIPLE EXPANSION
HIGH DUTY
PUMPING ENGINE.

ONE OF FOUR
SUPPLIED TO
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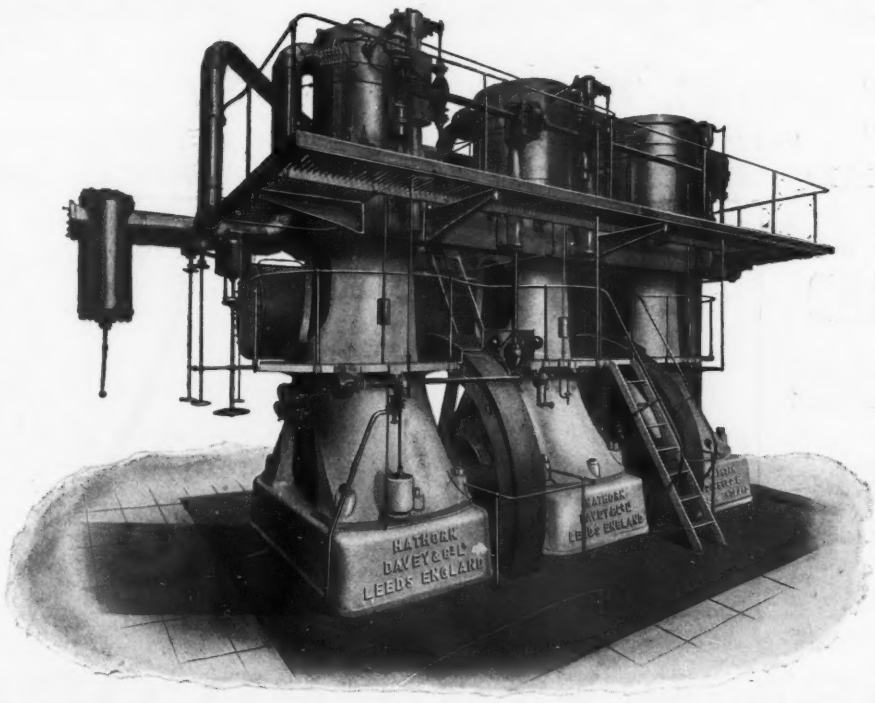
Sewage Works,
Mines, &c. &c.



OFFICIAL TRIAL
By PROFESSOR ORR,
Transvaal University.

ENGINE DIMENSIONS.

Cylinders, 23, 43 and 64in. diam
Rams, 3 single-acting, direct-coupled.
Stroke, 3ft.
Steam pressure, 180 lb. superheated, 120 deg. Fah.

ENGINE RESULTS.

Actual water pumped into reservoir per hour, 106,353 gallons.
Effective head in one lift, 975·5ft.
Steam consumption per I.H.P. per hour, 10·324 lb.

DUTY.

In water actually delivered into reservoir 183·6 million foot lb. per 1000 lb. of steam.
Combined Mechanical Efficiency of Engine and Pumps, 93·41 %.

N37

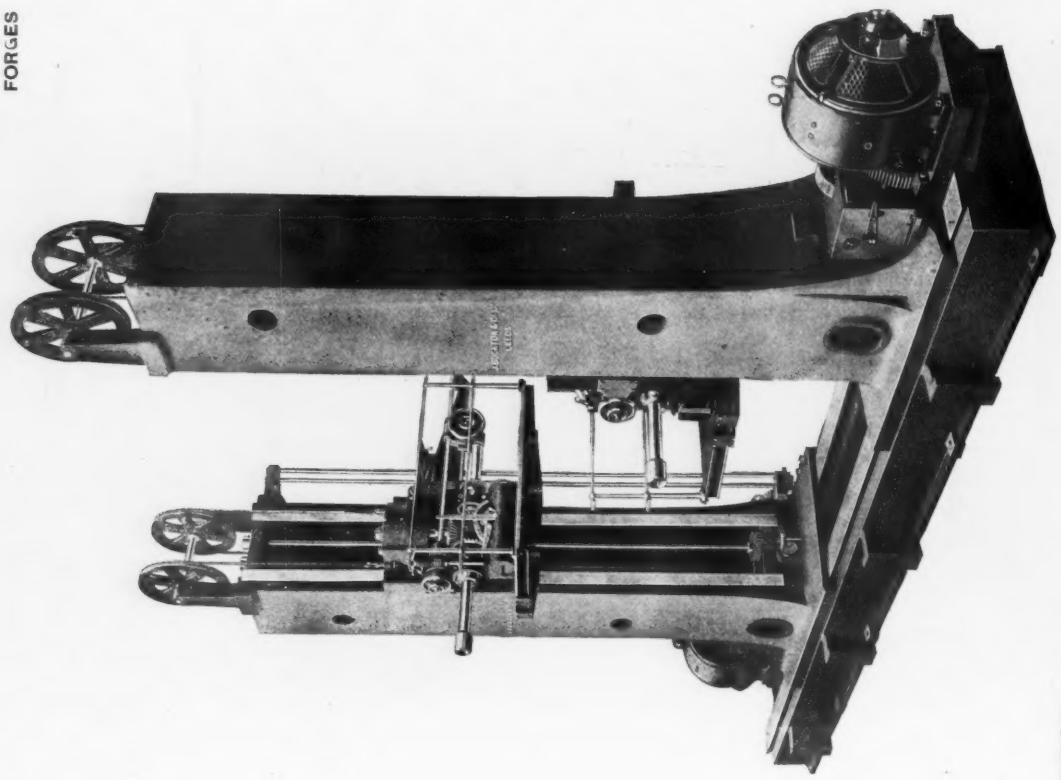
WORLD'S RECORD FOR STEAM ECONOMY.

HATHORN DAVEY & CO., LTD., LEEDS

D

BUCKTON

MACHINE TOOLS
FOR HEAVY ORDNANCE
TURBINES ENGINES BOILERS
LOCOMOTIVES
STEEL WORKS
FORGES



DRILLS

VERTICAL
UNIVERSAL HORIZONTAL
CHAIN CABLE AND ANCHOR
TESTING MACHINES

JOSHUA BUCKTON & CO LTD
LEEDS ENGLAND

A819

JAMES HOWDEN & CO., LIMITED

Manufacturers of

High-speed Engines

FOR

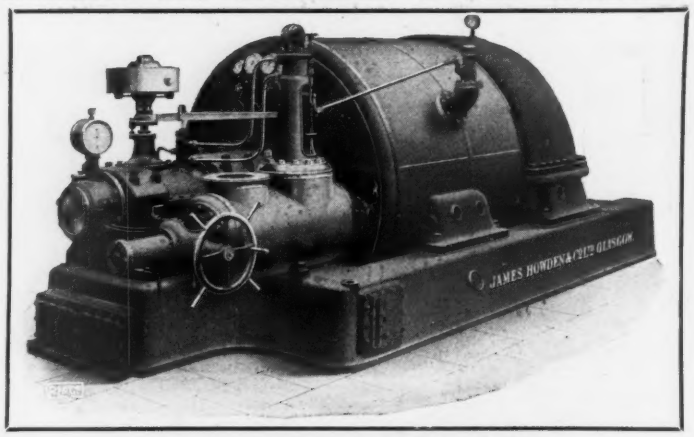
ELECTRIC LIGHTING, TRACTION, TRANSMISSION OF POWER, &c. &c.

Patented Improvements giving Highest Efficiency.

STANDARD SIZES IN STOCK FOR EARLY DELIVERY.

COMPOUND AND TRIPLE-EXPANSION ENGINES

From 5 B.H.P. to 2000 B.H.P.



2000 kwt. Impulse Steam Turbine, 1500 Revs.

MANUFACTURERS OF

IMPULSE STEAM TURBINES

OF HIGH, LOW, & MIXED PRESSURE TYPES.

PATENTEES & MANUFACTURERS of

HOWDEN'S FORCED DRAUGHT

2,925 *Installations on Land and Sea, aggregating over* **Ten Millions I.H.P.**

X16

JAMES HOWDEN & CO., LTD., Scotland Street, GLASGOW.

THE

BENN FRICTION CLUTCH.

PATENTS 8854, 1899; 19958, 1901, &c.

THIS CLUTCH IS STARTED AND STOPPED BY OUTSIDE ACTUATING GEAR AS USUAL, BUT PROVIDES ITS OWN INDEPENDENT DRIVING PRESSURE WHEN RUNNING.

SELF-LOCKING WITHOUT STRAINING OF PARTS OR DECREASE OF GRIP.

STANDARD FITTINGS FOR THE

TRADE MARK E T O P

ECONOMICAL TRANSMISSION OF POWER.

BEARINGS, PULLEYS, SHAFTING,

TRADE MARK E T O P

WRITE FOR CATALOGUE.

380,000 H.P. WORKING

NOT AFFECTED BY CENTRIFUGAL ACTION.

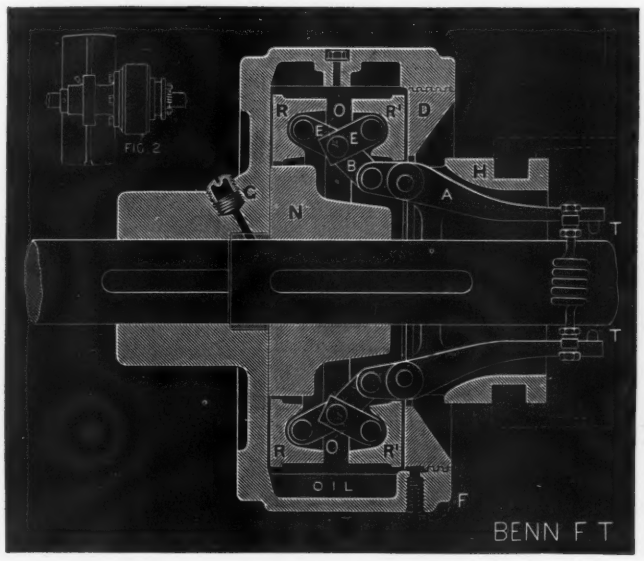
SUITABLE FOR HIGH SPEED.

SIMPLE EXTERNAL ADJUSTMENT IN LINE OF WEAR.

NO END THRUST ON SHAFT OR BEARINGS.

AMPLE LUBRICATION BY OIL BATH IN SHELL.

CONTINUOUS & EVENLY-LOADED FRICTION SURFACES.

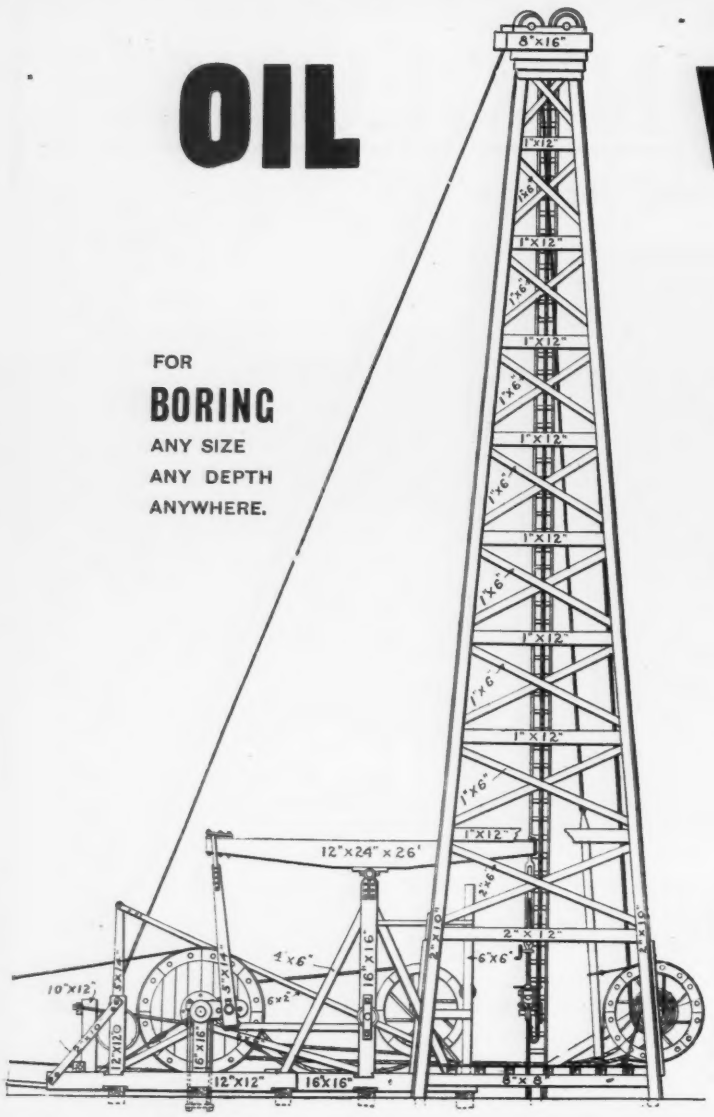


SOLE BRITISH MANUFACTURING LICENSEES, C1258

THE UNBREAKABLE PULLEY & MILLGEARING CO., LD.

WEST GORTON (58), MANCHESTER, & 56, CANNON ST., LONDON.

OIL WELL SUPPLY COMPANY of PITTSBURGH, PA., U.S.A.



FOR **BORING**
ANY SIZE
ANY DEPTH
ANYWHERE.

EVERYTHING SUPPLIED AS REQUIRED TO DRILL FOR **OIL, GAS, WATER, &c.**

Sole Manufacturers of the **'COLUMBIA' ALL-STEEL** *Portable* **DRILLING MACHINE.**

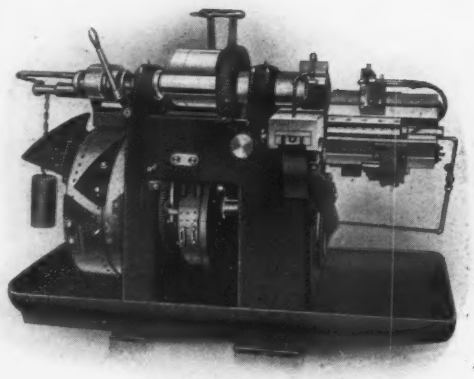
Steel Derricks and Complete Outfits in steel for extreme temperatures and weather. When asking for estimates, please state depth of proposed wells; if for oil, water, or minerals; the country; and, if known, the approximate geological conditions.

OUR TOOLS AND SUPPLIES ARE IN USE ALL OVER THE WORLD.

DASHWOOD HOUSE, 9, NEW BROAD ST., **LONDON, E.C.**

CABLES: EATON, PITTSBURGH; WELLOCOY, LONDON. D465

GRIDLEY PATENT AUTOMATIC TURRET LATHE.



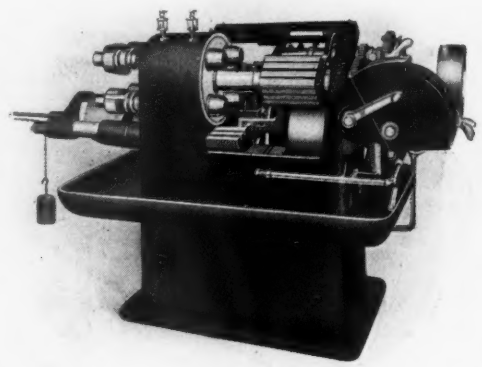
SINGLE SPINDLE GRIDLEY AUTOMATIC.

THE GRIDLEY AUTOMATIC TURRET LATHE will handle work fully twice as long as is within the capacity of the ordinary Turret Lathe, and turn it out in less time.

The tools are not held in the turret by the shank, but are fastened to the faces or the slides, and by placing two or more tools, one back of the other, one operation of the turret slide will accomplish the same work as would require two or three movements on other machines.

The **GRIDLEY AUTOMATICS** are more accurate, because the tools do not overhang; more efficient, because of their superior accommodation for special tools, their higher speeds, coarser feed and greater rigidity.

Gridley Catalogue with full particulars sent on application.



MULTIPLE SPINDLE GRIDLEY AUTOMATIC.

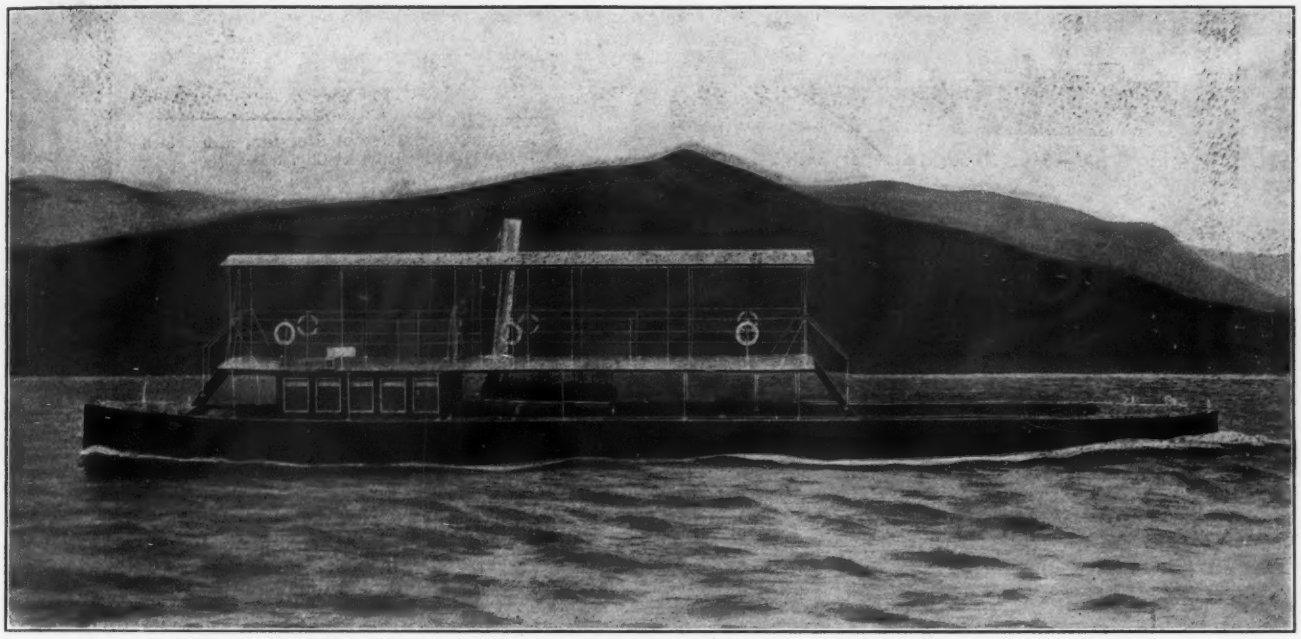
MANUFACTURED BY— **CRAVEN BROTHERS LTD.,**

VAUXHALL WORKS, OSBORNE ST., MANCHESTER. For Great Britain and Colonies and South America. Q411

MANNING, MAXWELL & MOORE, Sales Agents, New York, Philadelphia, Pittsburg, Cleveland, Chicago and St. Louis.
M. KOYEMANN, Charlottenstrasse 112, Dusseldorf, Germany, Holland, Belgium, Switzerland and Austria-Hungary.

SHALLOW-DRAUGHT LAUNCH, "YARROW SYSTEM."

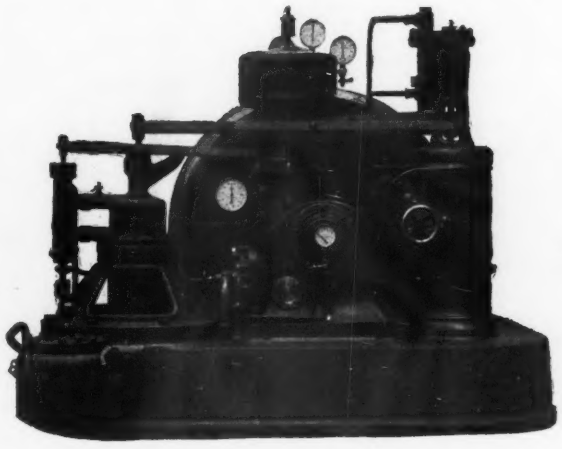
Built by - **YARROW & CO., Ltd., GLASGOW** (Formerly of POPLAR, LONDON.)



LENGTH—75ft. BEAM—9ft. 3in. DRAUGHT—12in. SPEED—10 Miles an Hour.

Messrs. **YARROW** make a **SPECIALITY** of **SHALLOW-DRAUGHT RIVER STEAMERS,** either propelled by a **STERN-WHEEL** or by **SCREWS WORKING IN TUNNELS,** fitted with **YARROW'S PATENT HINGED FLAP,** driven by **STEAM** or **INTERNAL COMBUSTION ENGINES.** N8

DICK, KERR & CO., Ltd.,



D.K.

STANDARD

MIXED-PRESSURE

STEAM TURBINE.

HEAD OFFICE: ABCHURCH YARD, CANNON STREET, LONDON, E.C. Y493

JOHN BROWN & CO., Ld.

Atlas Works, Sheffield, and Clydebank, near Glasgow. London Office: 8, The Sanctuary, Westminster, S.W.

BUILDERS OF PASSENGER & CARGO STEAMERS.

And Specially of First-class High-speed Ocean Steamers, up to the Largest Size and Power.

WARSHIPS OF ALL TYPES.

BATTLESHIPS, CRUISERS, & TORPEDO BOATS,

AS BUILT FOR THE BRITISH, SPANISH, RUSSIAN, JAPANESE, AND NETHERLAND GOVERNMENTS.

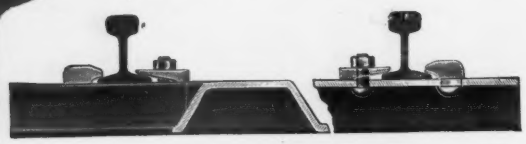
Manufacturers of ARMOUR PLATES.

ATLAS SELF-HARD STEEL FOR HIGH-SPEED MACHINES.

Largest Sizes of Cranks and Straight Shafting, Hydraulic Pressed, Solid or Hollow, Rough Machined or Finished Boiler Flue and other Marine Specialities. Railway Material. Steel Castings. Foundry and Forge Pig Iron. G844

All Sections of Rails from 9 lbs. per yard and upwards.

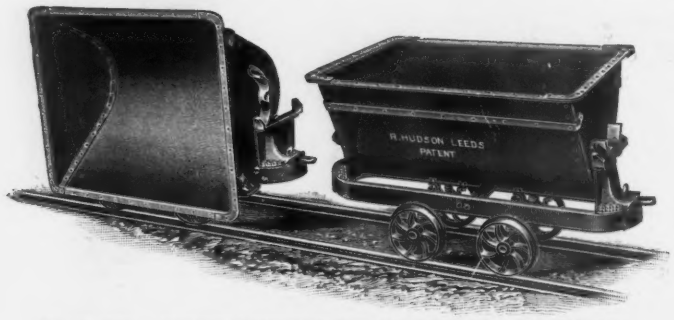
Section No. E 168



No. E 190.—Steel Trough Sleeper, with Bolted Clips.

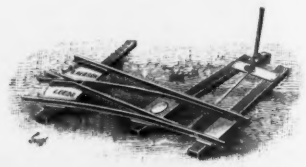
No. E 191.—Corrugated Steel Sleeper, with Clutch Bolt and Rivetted Clip.

Section No. E 167.



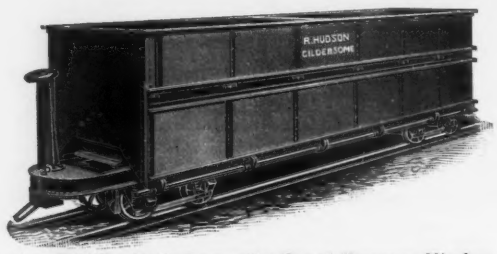
No. E 480.—Patent V Shaped Steel Double Side Tip Wagon.

No. E 116.—Self-contained Ball-bearing Turntable, with Flush Rails, for carting over.

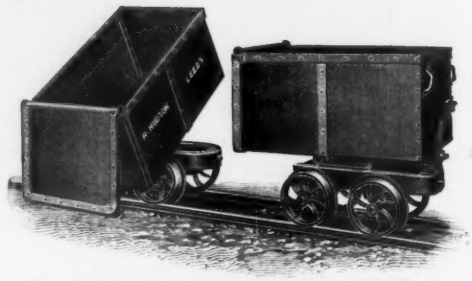


No. E 10.—Left-hand Steel Points and Crossings.

No. E 187.—Steel Side Door Hopper Wagon.
Discharging on either side of rail.



No. E 408.—High Capacity Steel Hopper Wagon with Side Discharge.

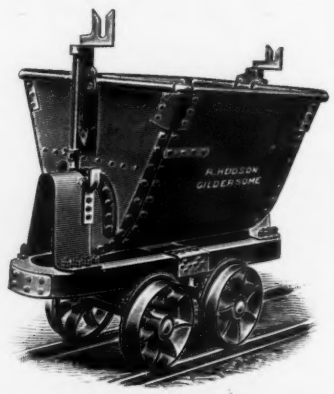


No. E 482.—Side and End Tip Mine Car with End Door.

R. HUDSON,

Gildersome,

near LEEDS.



No. E 398.—Standard Diamond Fields Truck
with Large and Small Jockey.

No. E 399.—Patent Side Tip Wagon
with Basket Top.
For conveyance of very light material.

Manufacturer of

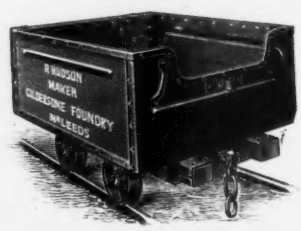
PORTABLE RAILWAY

and

TIP WAGONS,

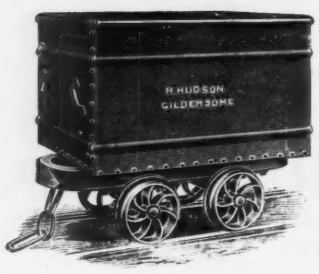
COLLIERY TUBS, &c.

No. E 19.—2-Wheeled Barrow.

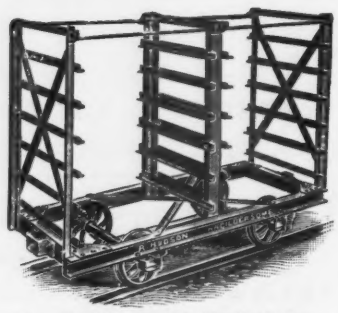


No. E 87.—Pressed Steel Colliery Tub,
with Woll Bottom for Thin Seams.

No. E 107.—Solid Welded Steel Sinking Bucket (or Bowk).



No. E 395.—Pressed Steel Colliery Tub, with Channel Steel Frame.



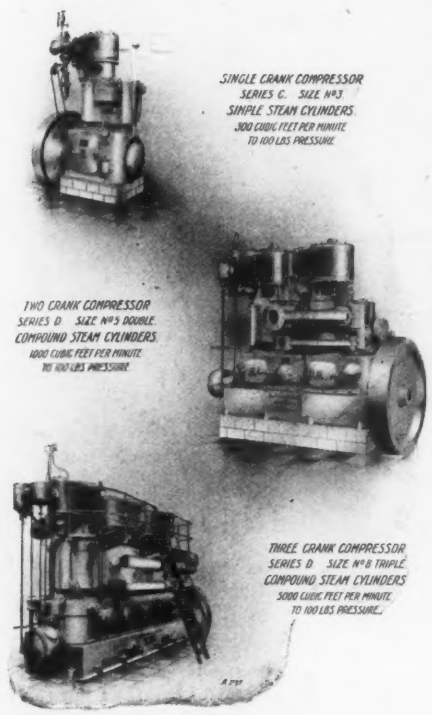
No. E 402.—Brick Drying Car, with Roller Bearings.

No. E 439.—Single Hearth, 3½ft. x 4ft. size.
Bottom Blast Type.

"Sentinel" Air Compressors

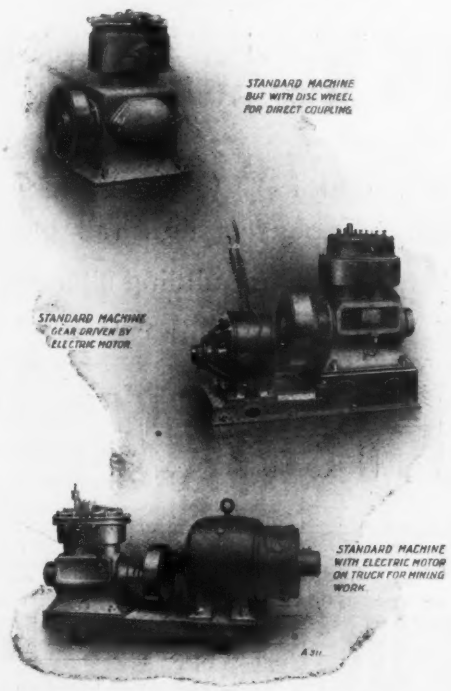
. . ARE . . .

Simple in Construction, Economical, Reliable, Moderate in Cost.


SINGLE CRANK COMPRESSOR
SERIES C. SIZE No 3
SIMPLE STEAM CYLINDERS
300 CUBIC FEET PER MINUTE
TO 100 LBS PRESSURE
TWO CRANK COMPRESSOR
SERIES D. SIZE No 5 DOUBLE
COMPOUND STEAM CYLINDERS
1000 CUBIC FEET PER MINUTE
TO 100 LBS PRESSURE
THREE CRANK COMPRESSOR
SERIES D. SIZE No 8 TRIPLE
COMPOUND STEAM CYLINDERS
5000 CUBIC FEET PER MINUTE
TO 100 LBS PRESSURE.

OVER 600 REPEAT ORDERS.

Standard sizes from 25 to 8500 cubic feet of free air per minute.



THE COMMERCIAL EFFICIENCY OF AIR COMPRESSORS.

The above efficiency depends upon three factors of primary importance — Power Cost, Running Cost and First Cost. Detailing these three factors we have:—

POWER COST.

Efficiency of Compression.
Internal Friction and Heating.
Mechanical Efficiency.

RUNNING COST.

Durability.
Automatic Oiling.
Automatic Governing.
Low Oil Consumption.

FIRST COST.

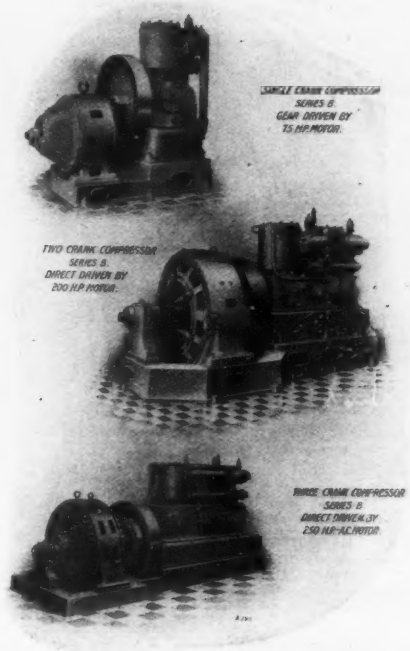
Volumetric Efficiency.
Moderate Price.
Cost of Erection.
Cost of Foundation.
Cost of House Room.

If you wish to purchase so scientifically as to get the best value in Power Cost, Running Cost, and First Cost, not only for a few years but for many years, you should take our 'Sentinel' Air Compressor design and the next best other, and go over them point by point, as detailed in our Catalogue No. 10 Air. It is a simple matter, and if done even roughly, the result will be beyond doubt.

Finally, we would urge that as a rule, a buyer gets the value he deserves, and in such things as Air Compressors, where the value varies so enormously, it pays very handsomely to go thoroughly into the matter.

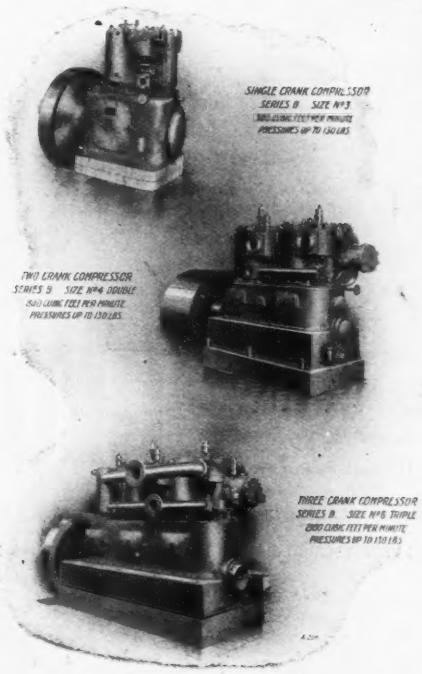
Our years of experience and the services of our experts are at your disposal.

Have you Catalogue No. 11 Air?



OVER 600 REPEAT ORDERS.

Nearly all the leading Engineers and Shipbuilders use one or more 'Sentinels.'


SINGLE CRANK COMPRESSOR
SERIES B SIZE No 3
300 CUBIC FEET PER MINUTE
PRESSURES UP TO 130 LBS
TWO CRANK COMPRESSOR
SERIES B SIZE No 4 DOUBLE
500 CUBIC FEET PER MINUTE
PRESSURES UP TO 130 LBS.
THREE CRANK COMPRESSOR
SERIES B SIZE No 6 TRIPLE
1000 CUBIC FEET PER MINUTE
PRESSURES UP TO 130 LBS

ALLEY & MacLELLAN, Ltd.,

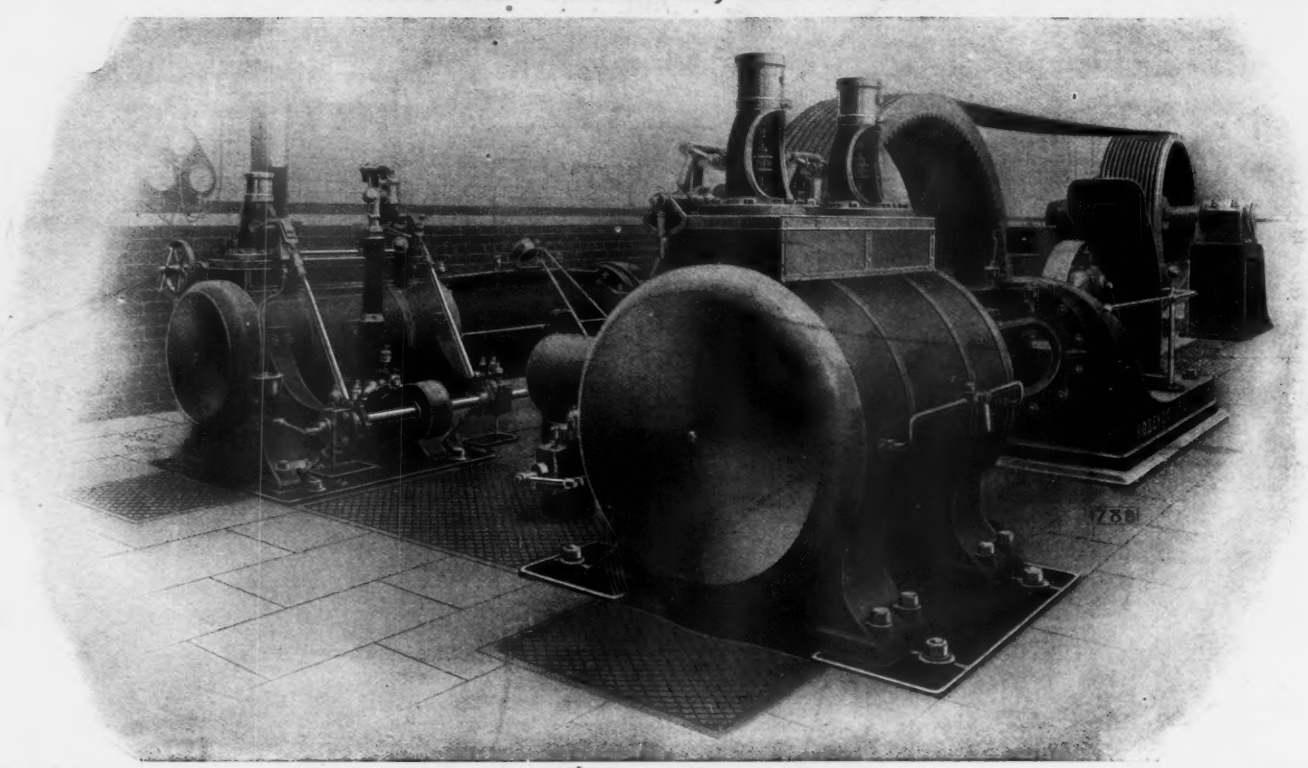
Sentinel Works, GLASGOW.

X18

E

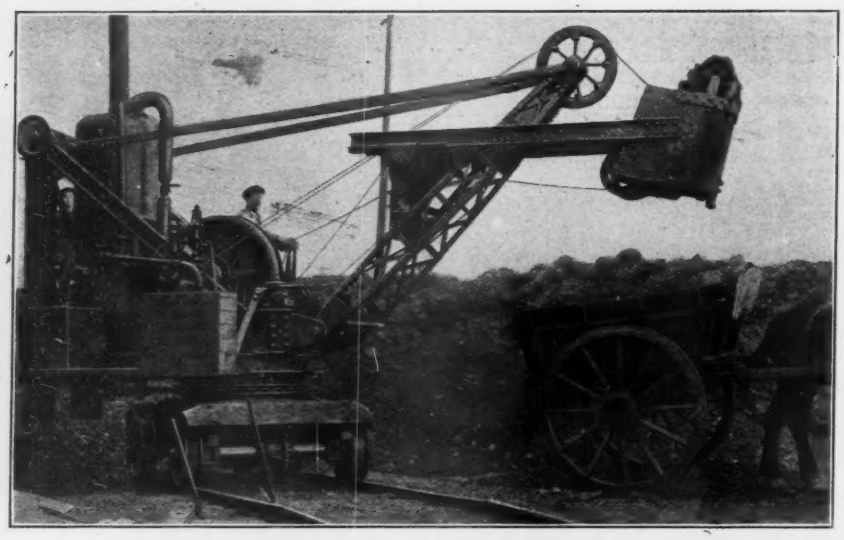
ROBEY & CO., LTD.,

GLOBE WORKS, LINCOLN.



SPECIALITY: SUPERHEATED STEAM ENGINES, with Patent Drop-Valve Gear.

FIXED ENGINES UP TO 4000 H.P. WINDING AND HAULING ENGINES WITH PATENT REVERSING GEAR AND PATENT DEVICE FOR PREVENTION OF OVERSPEED AND OVERWINDING. UNDERTYPES, HIGH PRESSURE AND COMPOUND. OVERTYPES, PORTABLES, TRACTION ENGINES AND TRACTORS. AIR COMPRESSORS UP TO 12,000 FT. FREE AIR. BOILERS OF ALL TYPES AND FOR ANY PRESSURE. COMPLETE MINING PLANTS. (Spl) 1057



RUBERY, OWEN & CO.,

DARLASTON, S. Staffs.

Telegrams—Roofs, Darlaston. Nat. Telephone—22, Darlaston.

HANDY NAVVY.

The navvy that pays on small jobs.
It is light, inexpensive and reliable.
Suitable for levelling building sites or loading up material into carts, &c. D316

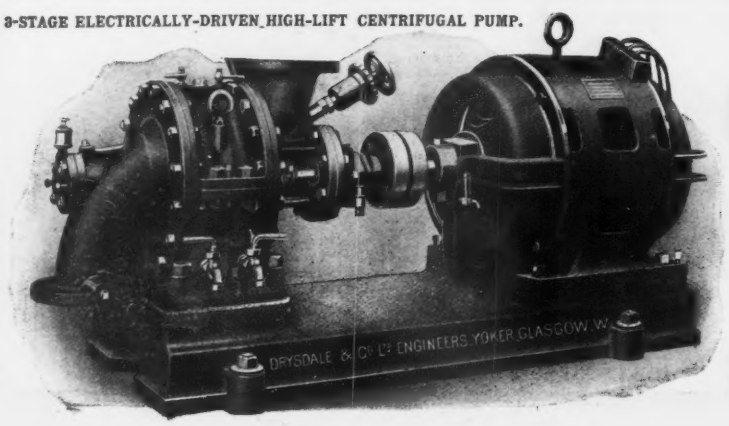
STEAM ENGINES
Corliss or Drop Valve Gears.
Highest Economy.

GEORGE SAXON LTD.,

OPENSHAW, MANCHESTER.

MILL GEARING
of every description.
See Illustrated Advt. on Dec. 23 Q707

3-STAGE ELECTRICALLY-DRIVEN HIGH-LIFT CENTRIFUGAL PUMP.



"BON-ACCORD" HIGH-LIFT
Horizontal or Vertical Spindle, Turbine Type

CENTRIFUGAL PUMPS

also LOW-LIFT CENTRIFUGAL PUMPS.

For Mine Pumping and Sinking,
Condensing, Draining, Dock Pumping,
Irrigating, Sand Pumping and Sewage Work, &c.

HIGH-SPEED ENGINES

For DRIVING DYNAMOS, PUMPS, FANS, &c.

DRYSDALE & CO., LTD., YOKER, GLASGOW, W.

Telegrams—BONACCORD, GLASGOW. WRITE FOR CATALOGUE. X190

ORR, WATT & CO.,
Steel Structural Engineers, LTD.
ROOF AND BRIDGE BUILDERS.
Hydraulic Pressed Steel Trough Flooring for Road & Railway Bridges, Buildings, &c.
LANARKSHIRE BRIDGE WORKS, Carfin, MOTHERWELL, Scotland. sm148

TOP-SPEED PLANING
on old machines by means of
Bateman Patent Plano-drive.
BATEMAN'S MACHINE TOOL CO., LTD.
Woodhouse Hill, nr. Leeds. Q720

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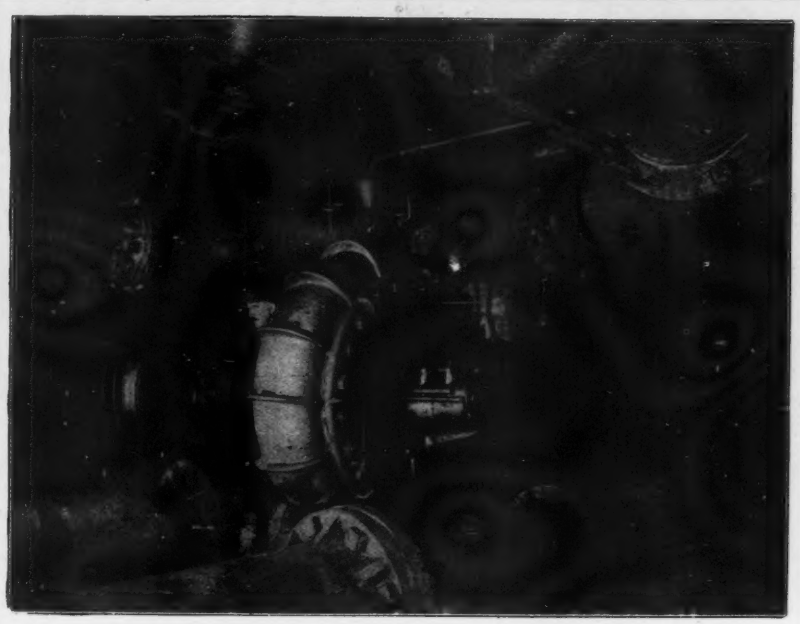
CLAY-WORKING PLANT. E1709
Colliery Plant. General Millwright.

JOHN H. STOREY & CO.
Engineers & Machine Tool Makers, HATCHAM, S.E.
Makers of Modern
MACHINE TOOLS
of all descriptions.
See Illustrated Advt. in Dec. 9th issue. D30

W. T. GLOVER & CO., LD.
Trafford Park, MANCHESTER.
Manufacturers of Electrical Wires and Cables and all classes of Cable-making Machinery. Q748

VICTORIA TURBO-PUMPS



Victoria Turbo-Pump supplied to the Lambton Collieries, Ltd.

AT A RECENT TEST THE PUMP IN THE ILLUSTRATION DELIVERED 2900 GALLONS OF WATER PER MINUTE AGAINST A HEAD OF 315 FEET; SPEED 1170 R.P.M.

THE EFFICIENCY GUARANTEED WAS 78 %, WHILST THAT OBTAINED ON TEST WAS 86 %.

THE VICTORIA TURBO-PUMP IS SUITABLE FOR HIGH LIFTS, AND HAS NO END THRUST AND NO HIGH PRESSURE GLAND.

SEND FOR CATALOGUE.

WILLANS & ROBINSON, LTD.
Victoria Works, RUGBY.
Spl TBT 1

PHOSPHOR BRONZE
COG WHEEL BRAND.
CASTINGS, INGOTS, SHEET, STRIP WIRE and ROD.
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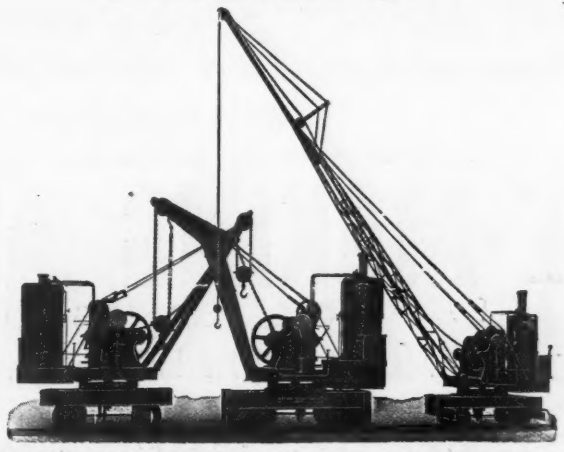
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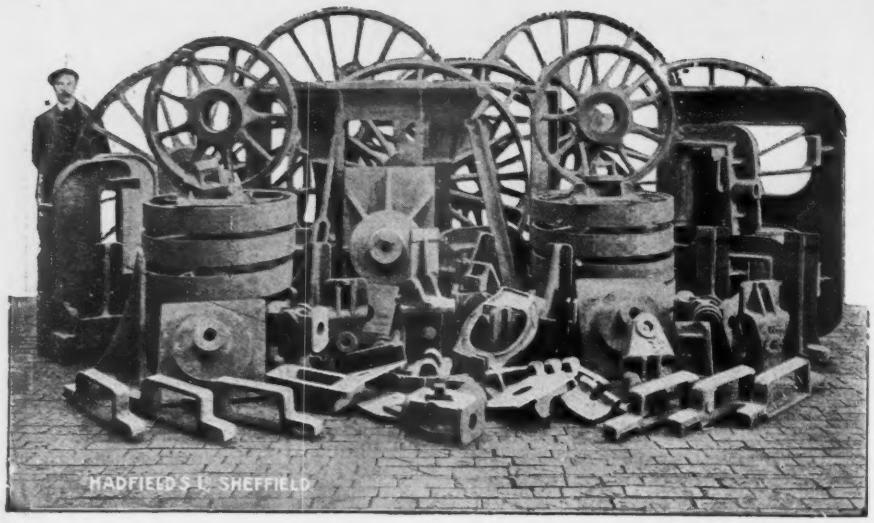

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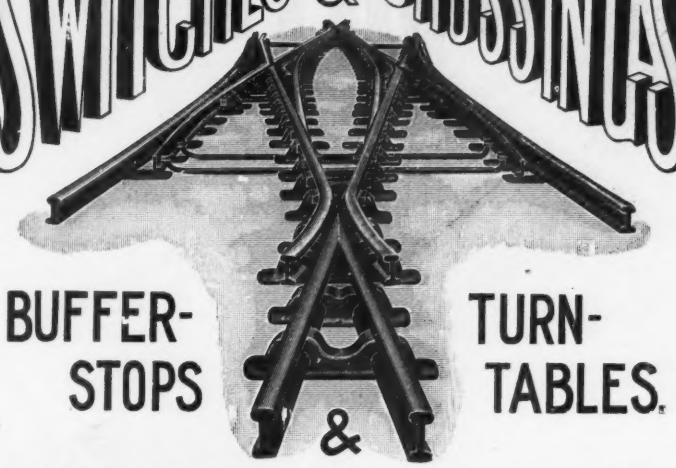

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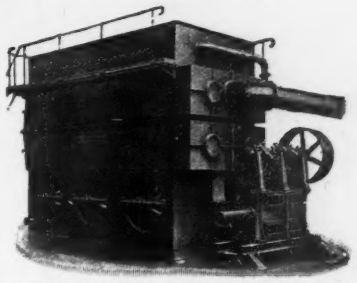

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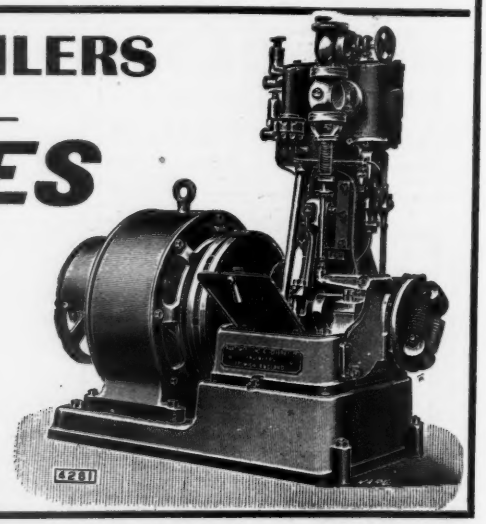

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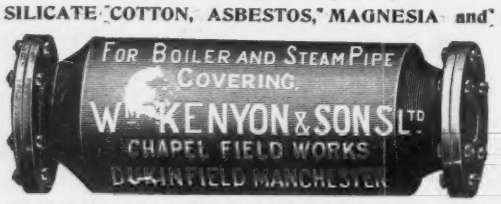

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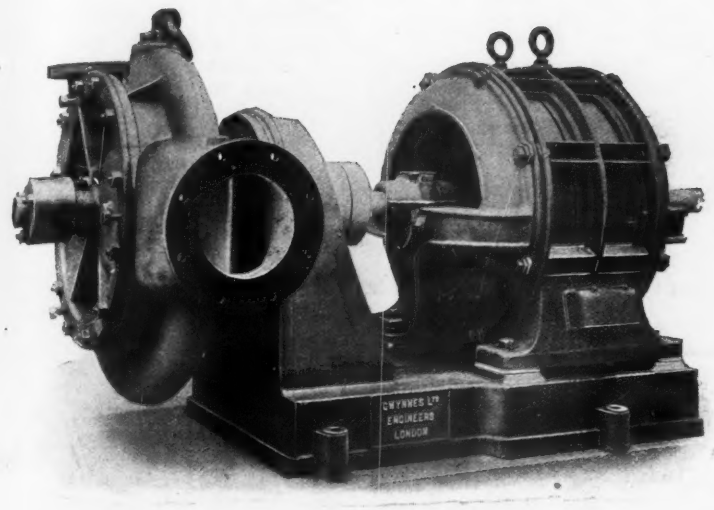

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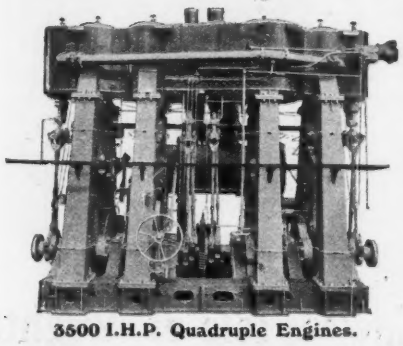

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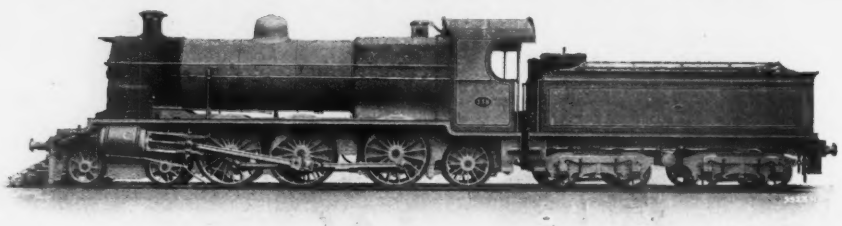

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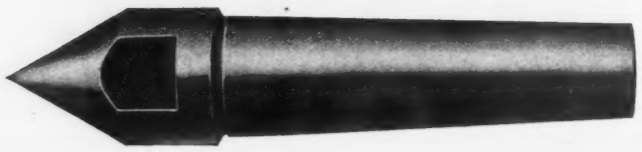

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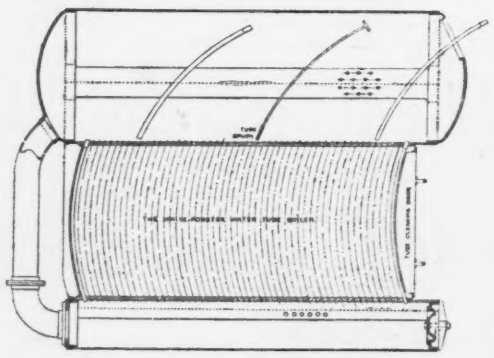

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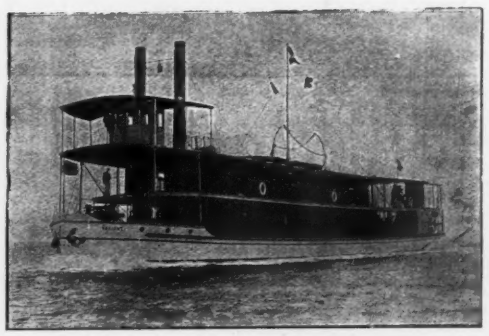

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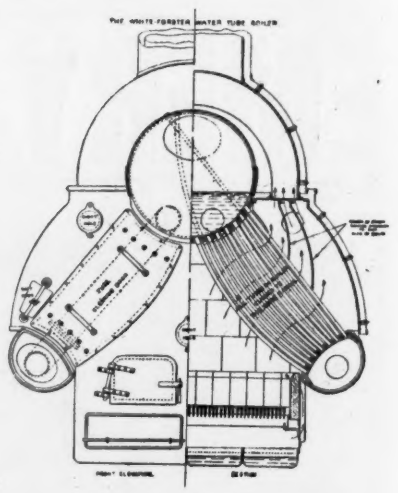

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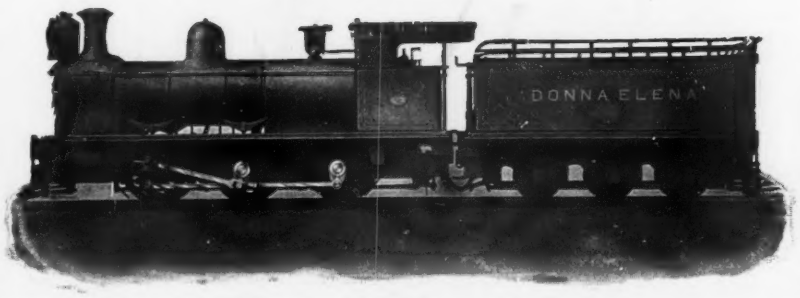

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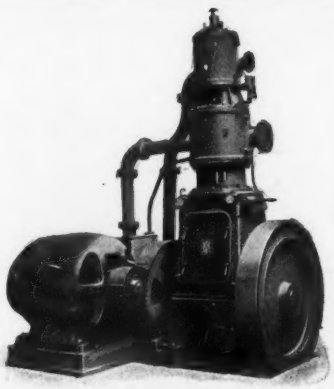

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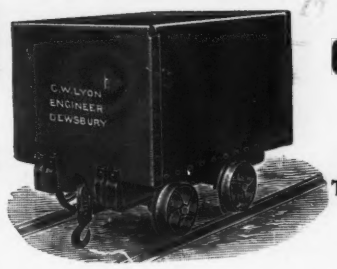

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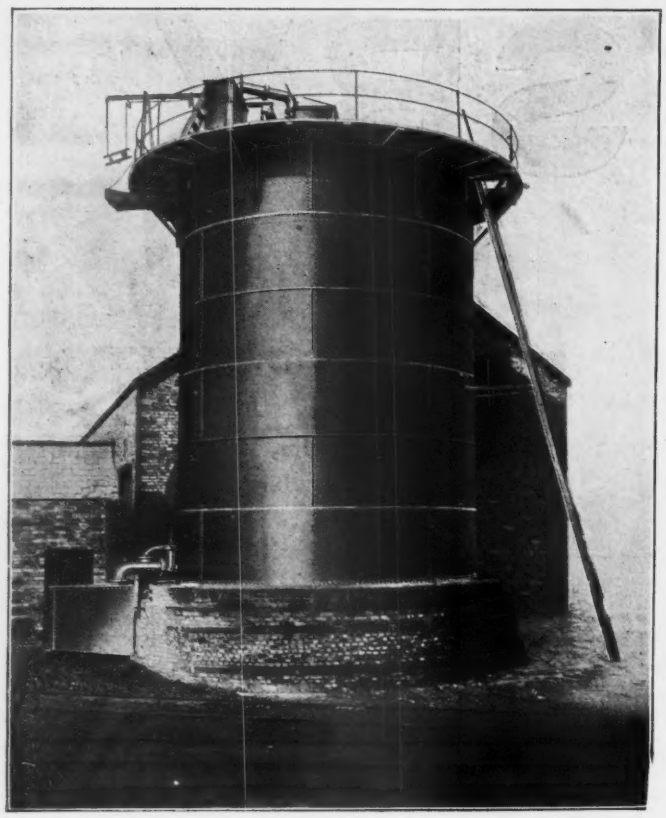

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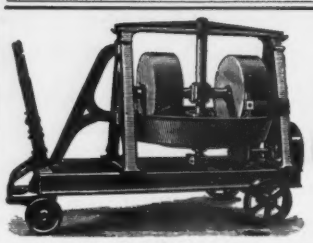

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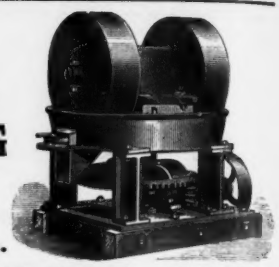

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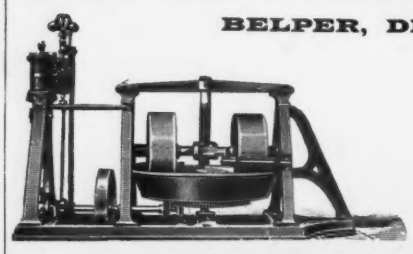

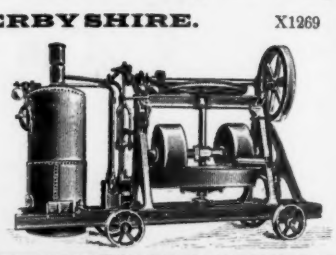

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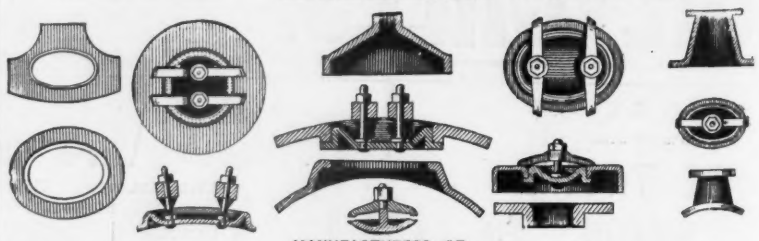

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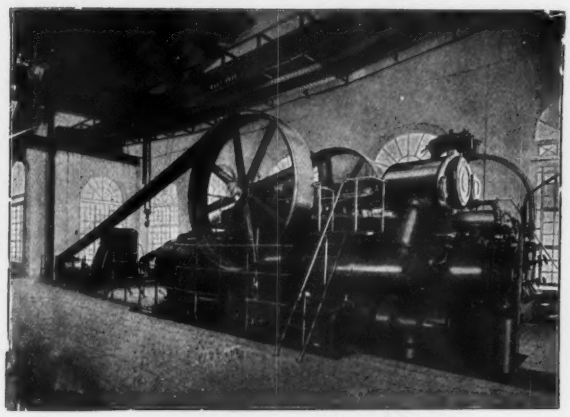

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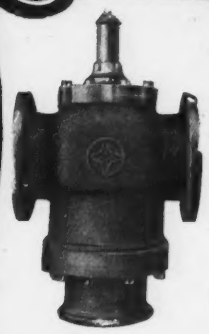

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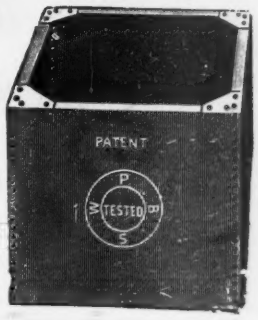

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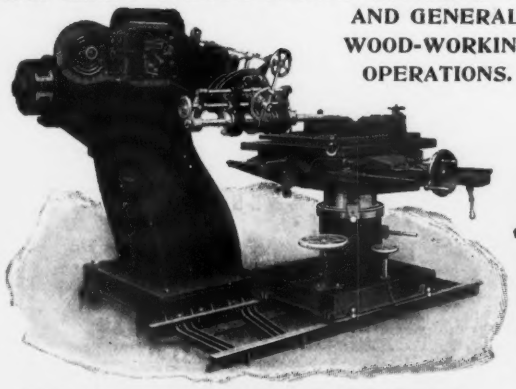

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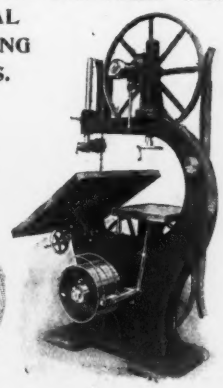

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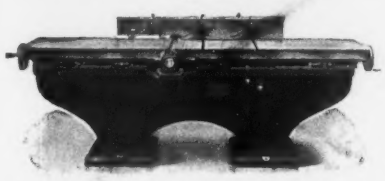

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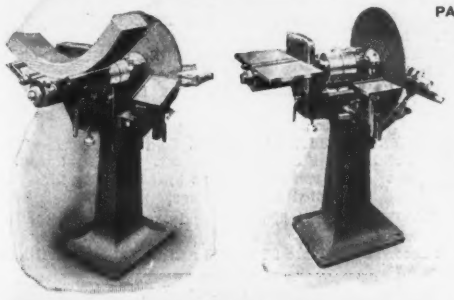

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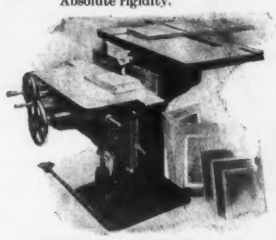

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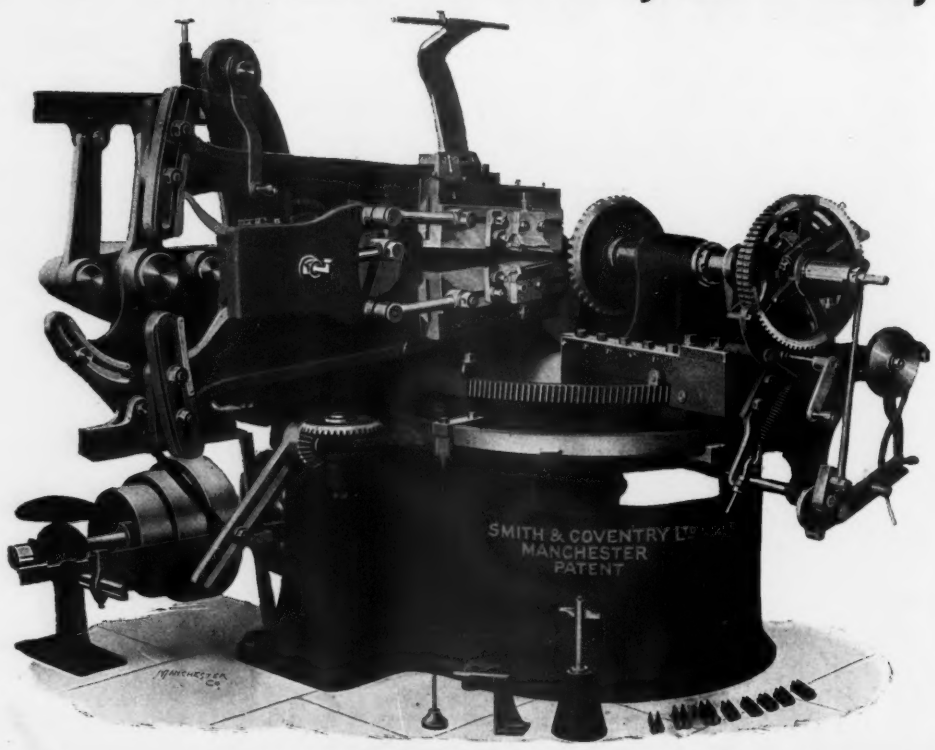

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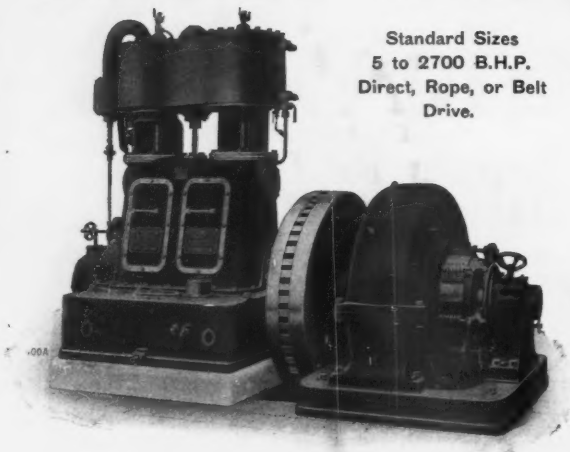

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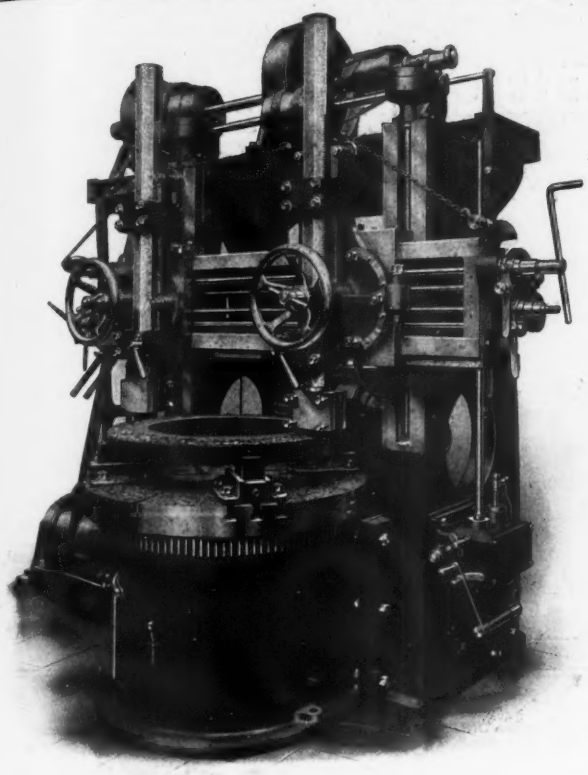

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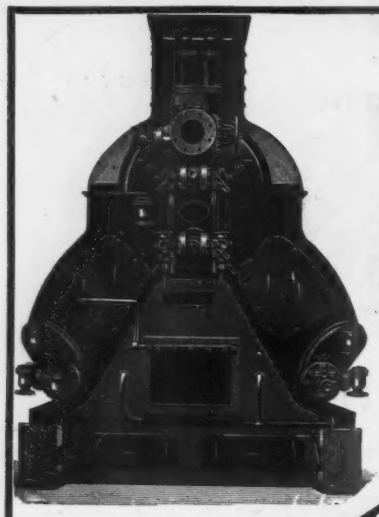

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PATENT
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LATEST DESIGN, 1909.

Curvature of all Tubes in all Rows the same. Any Tube in any position in the Boiler can be removed and replaced without touching or interfering with surrounding Tubes.

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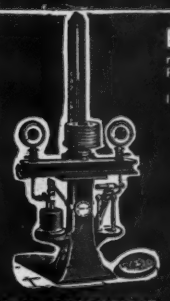
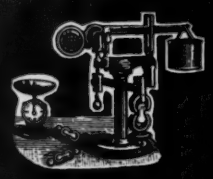


5040. DEADWEIGHT GAUGE TESTER.



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AIR COMPRESSORS.

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ANY DRIVE. ANY DUTY.

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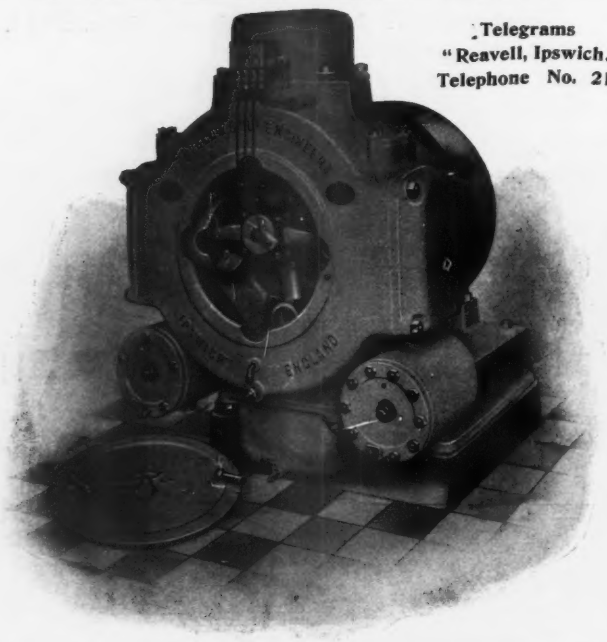

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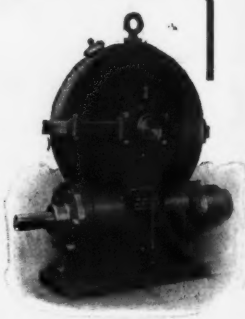

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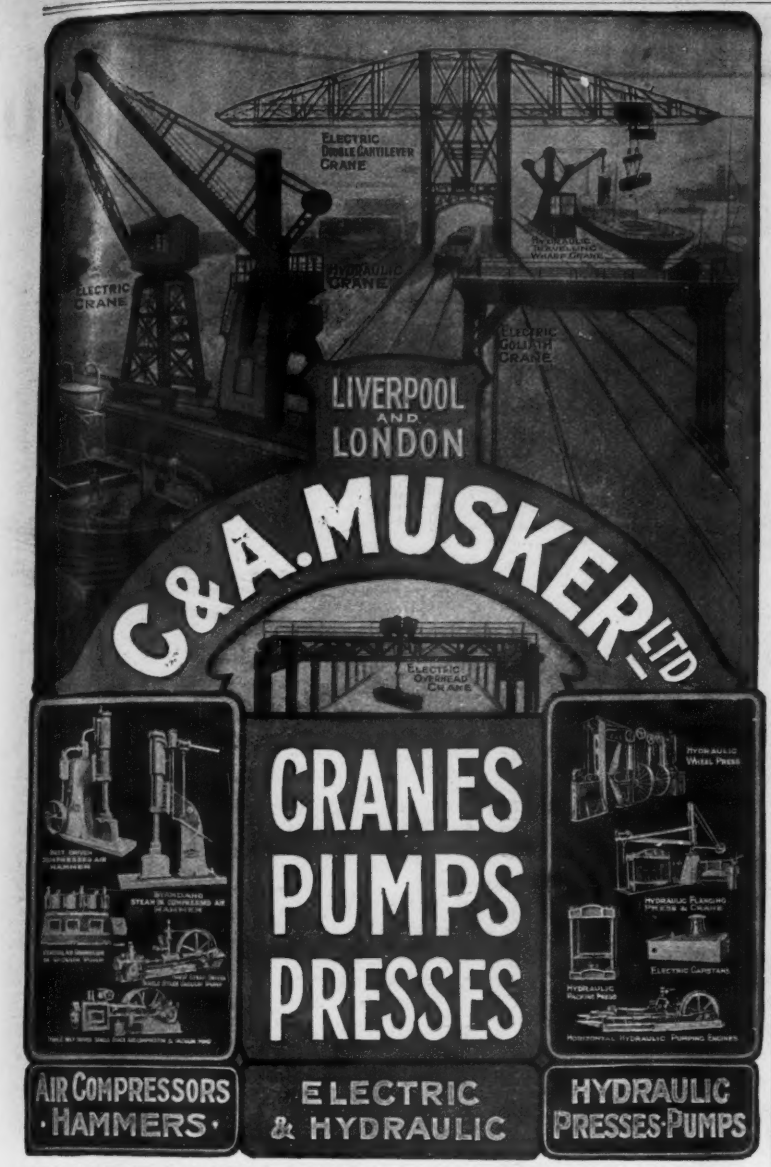

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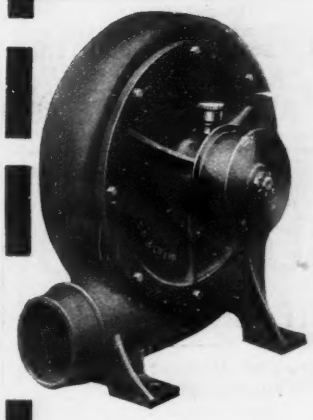
Built in several sizes from 10in. diam. upwards.



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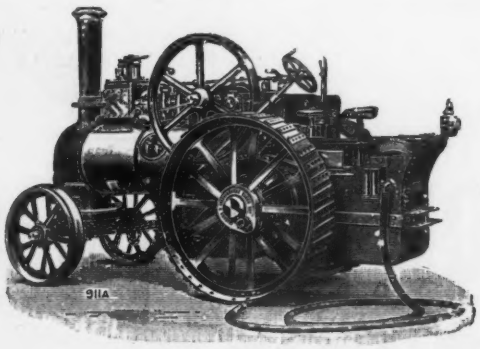

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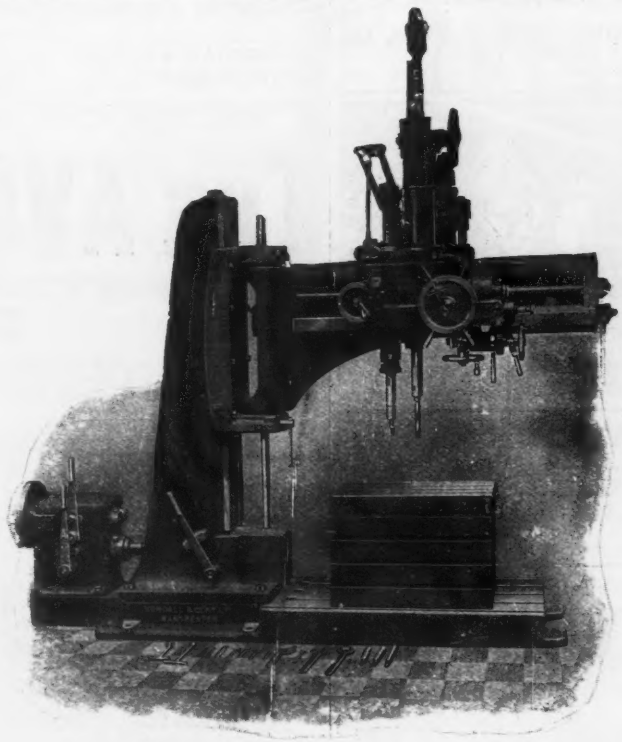
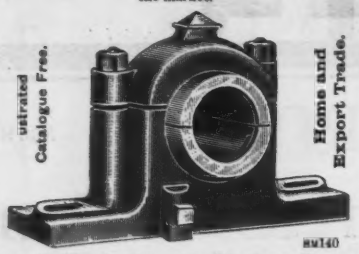


Block represents a 4ft. Dixon's Patent Radial Drilling and Tapping Machine with all latest improvements, including knock-off motion, ball bearing to trunnions of radial arm, all steel gears in saddle, 3·5 : 1 ratio drilling to tapping spindle, substantial gearing throughout, all cut from the solid. It will drill a 1in. hole at 6in. per minute feed, and taps same quicker than any other machine. Quite essential where there is much tapping. Wi 06

The 'AUSTIN' RING OILING PLUMMER BLOCK

The cheapest efficient Self-oiling Plummer Block on the market.



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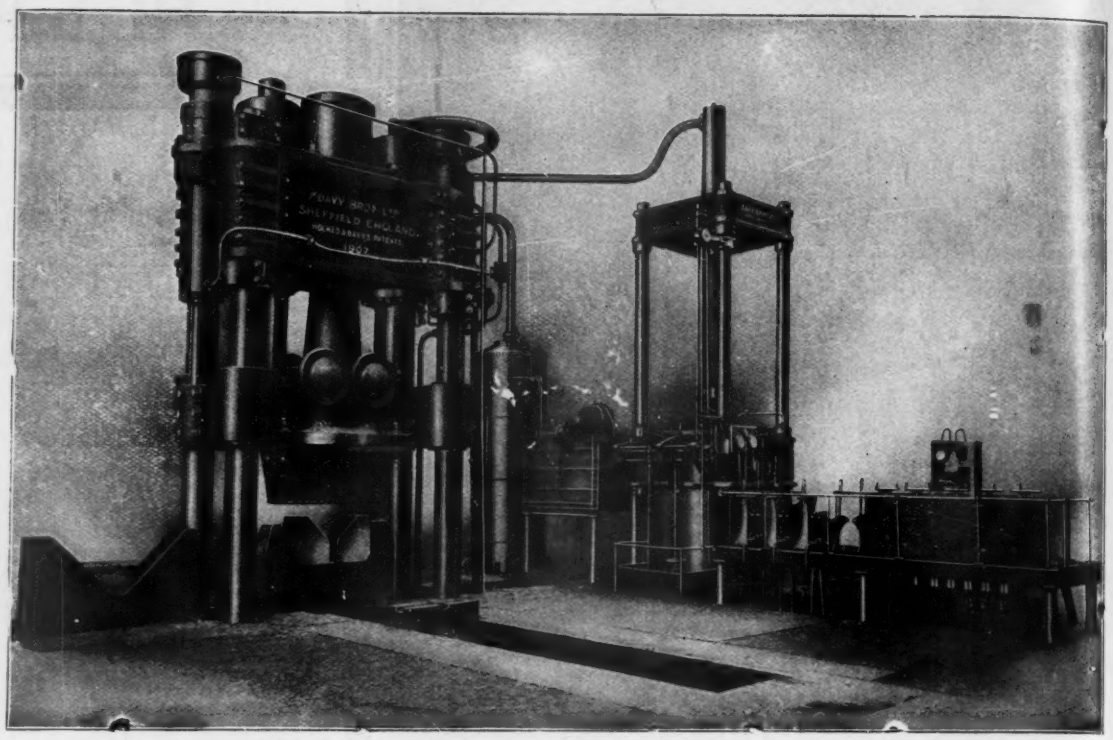

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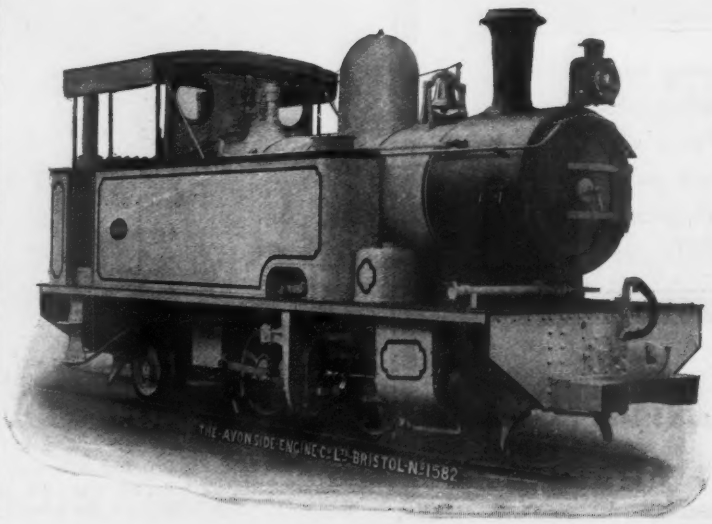

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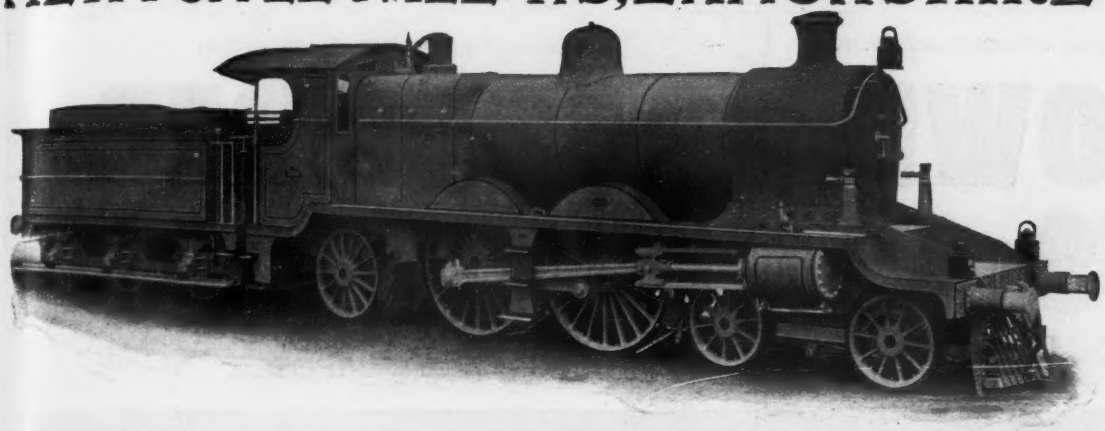

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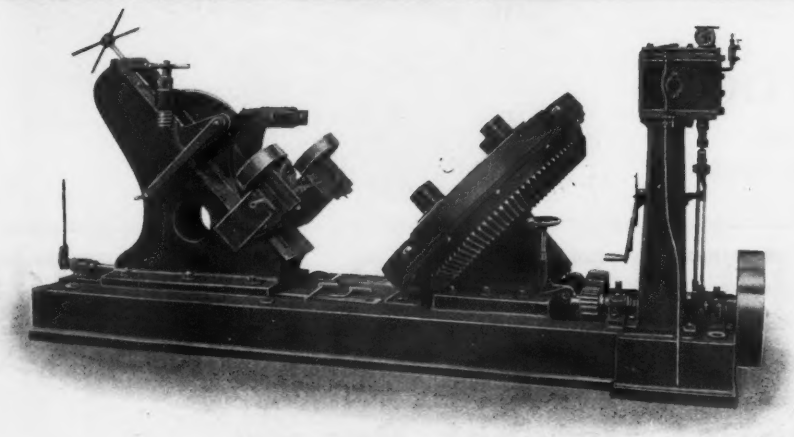

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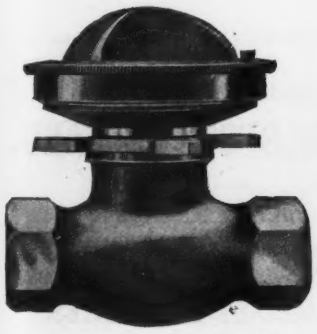

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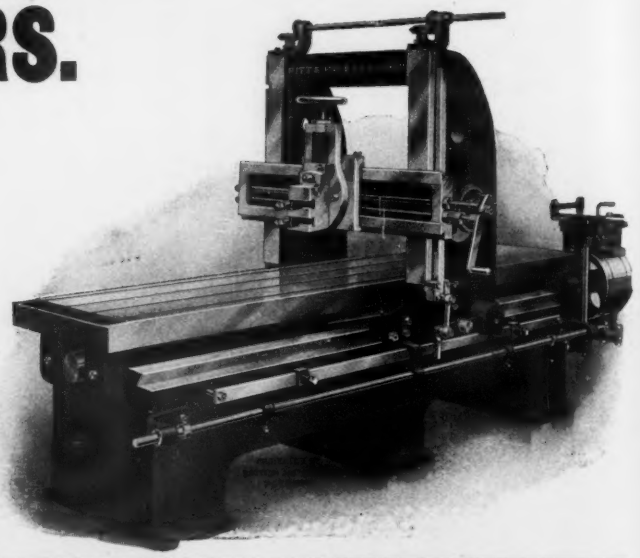

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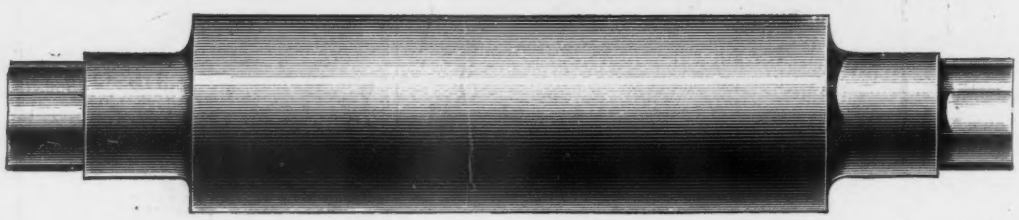

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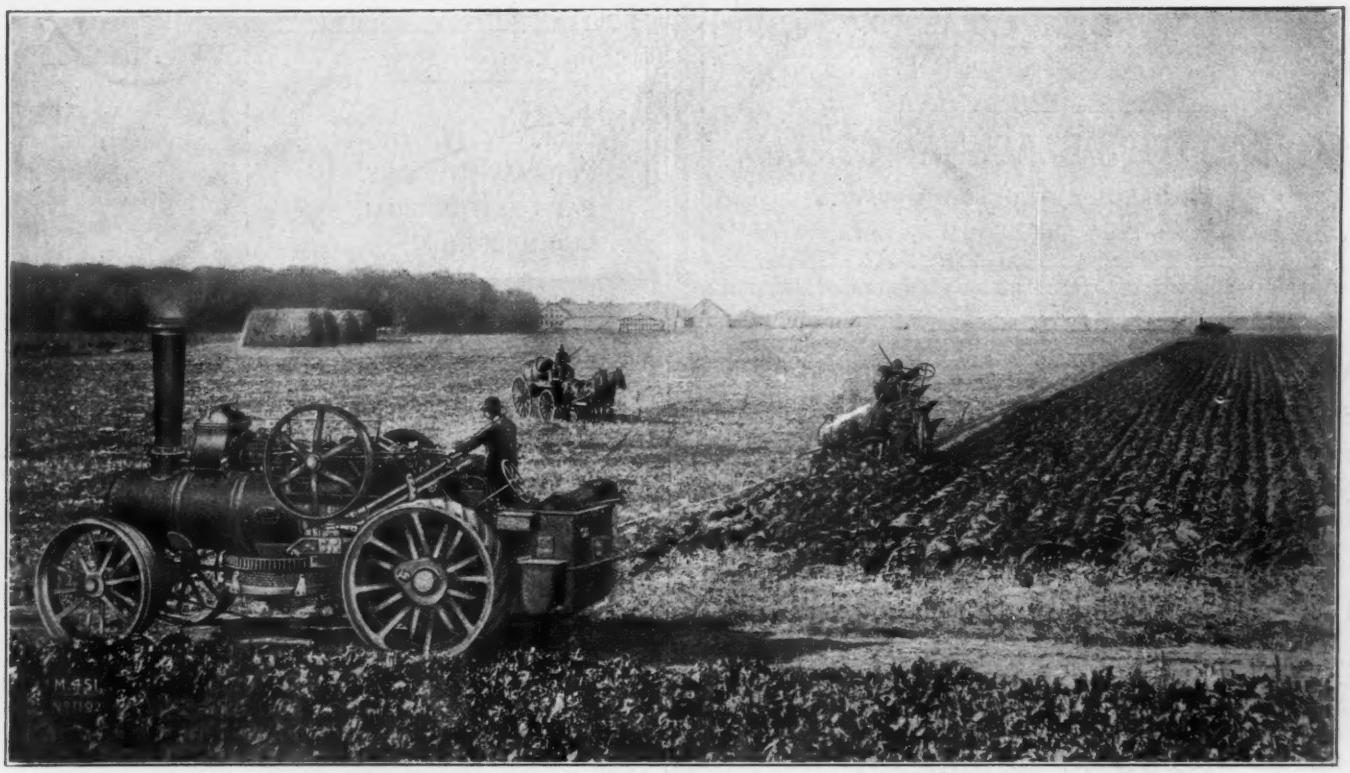

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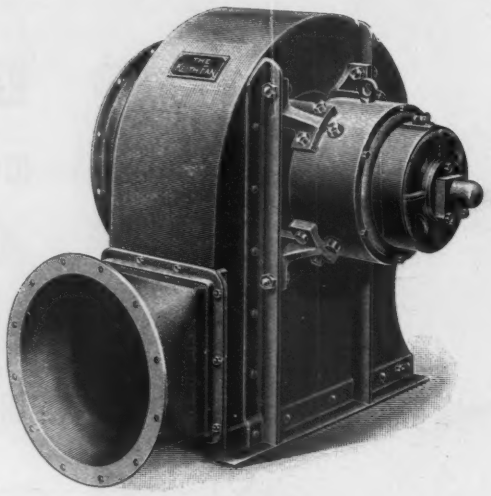

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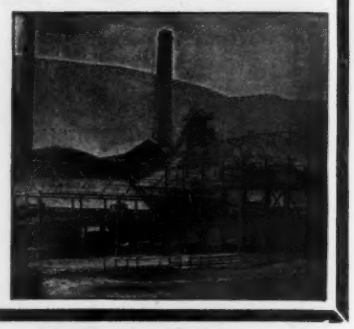

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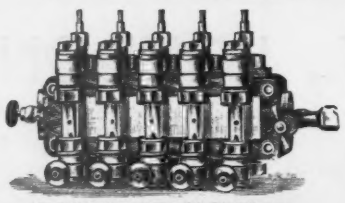

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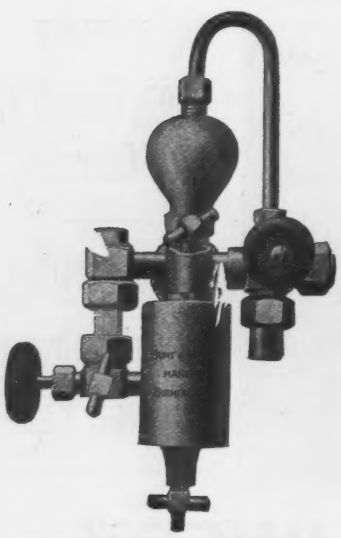

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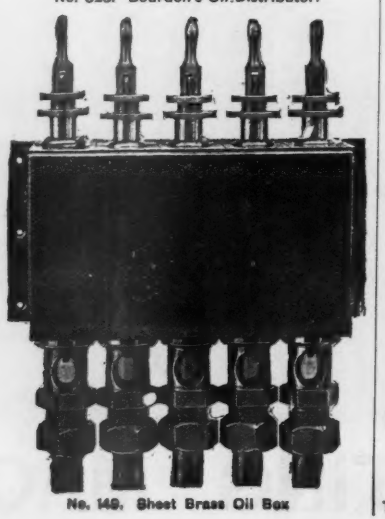

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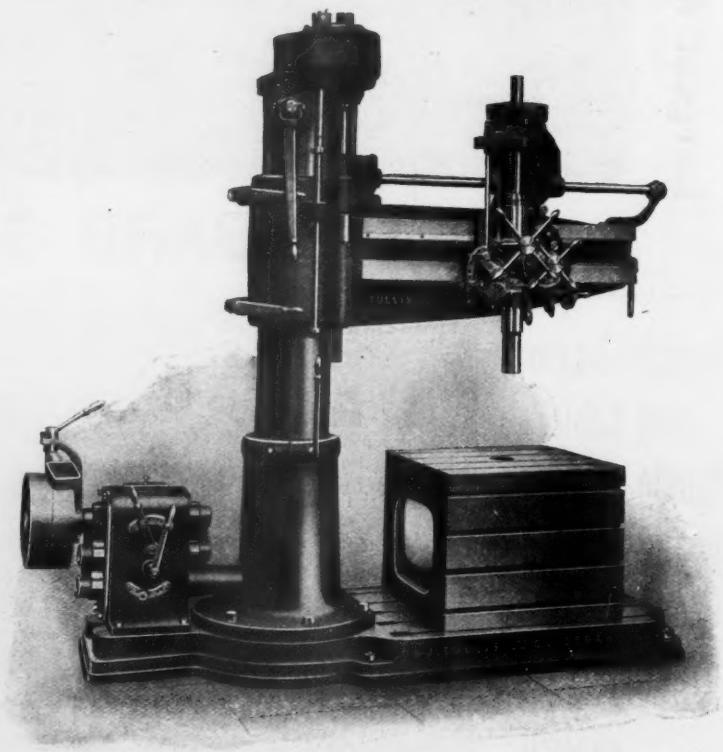

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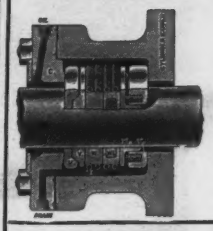

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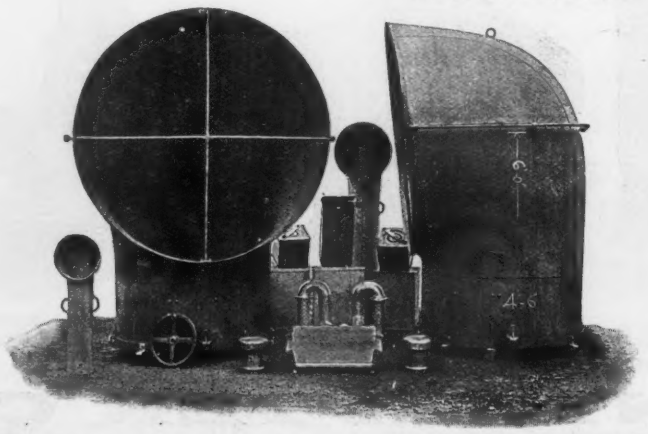

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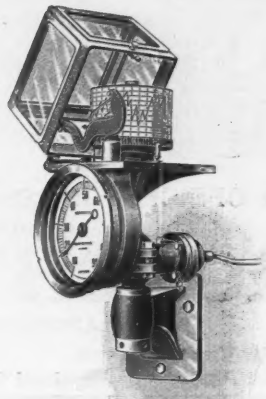

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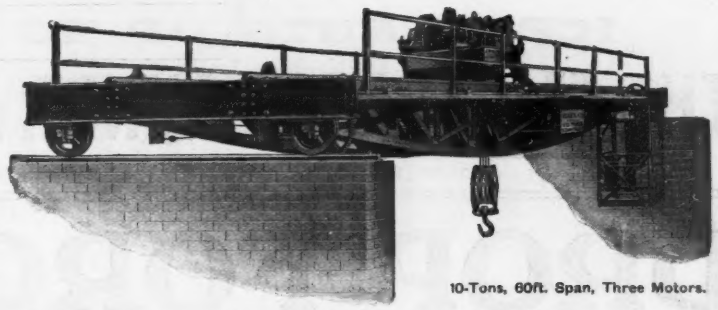

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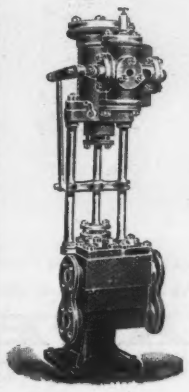

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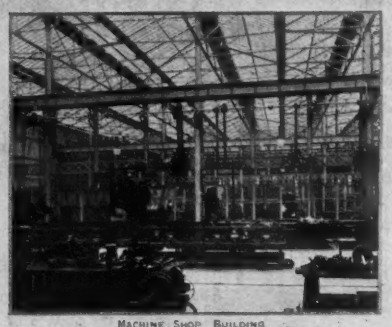

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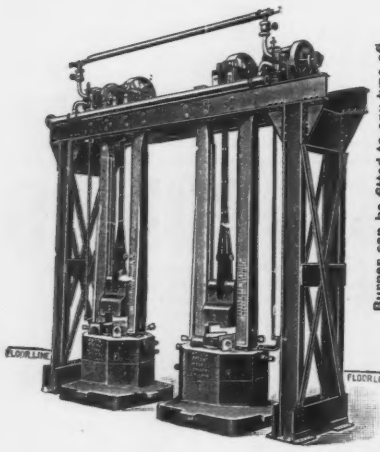

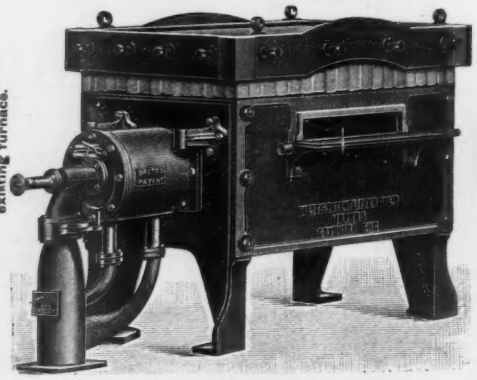

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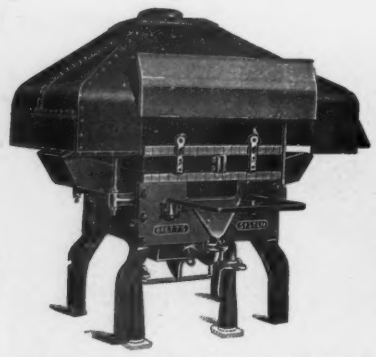

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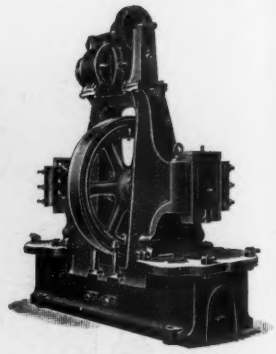

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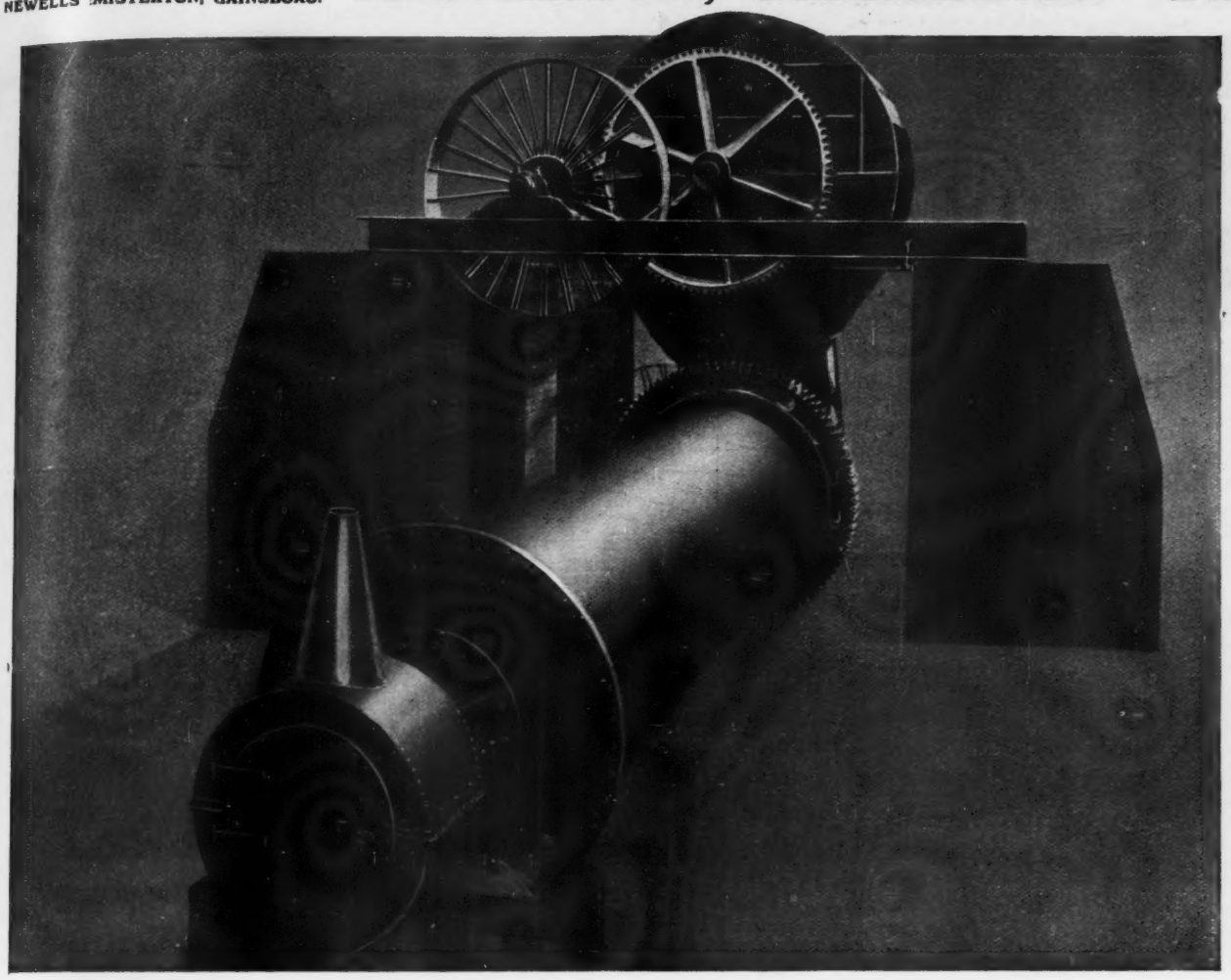

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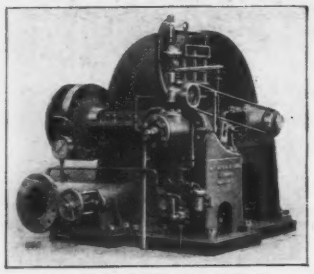

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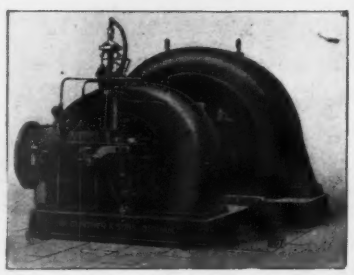

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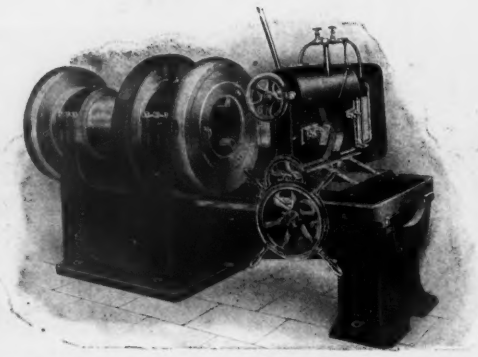

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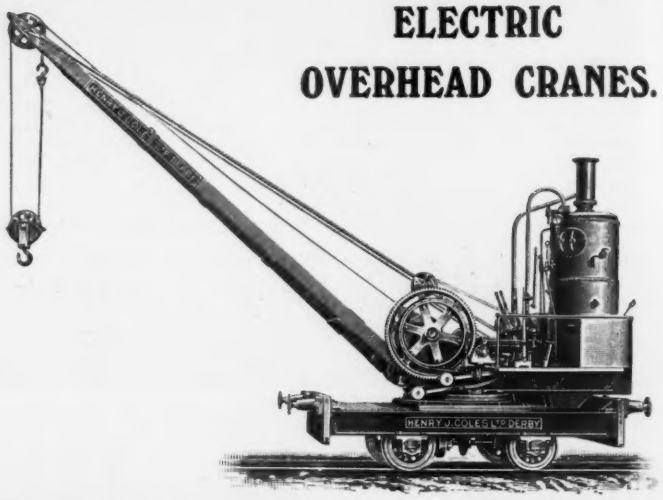

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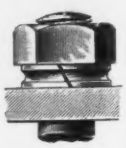

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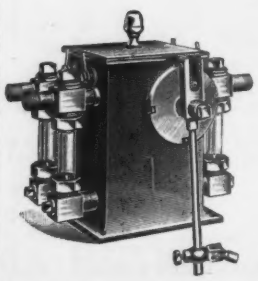

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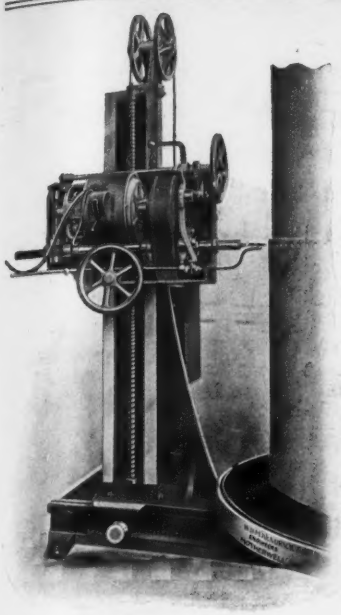

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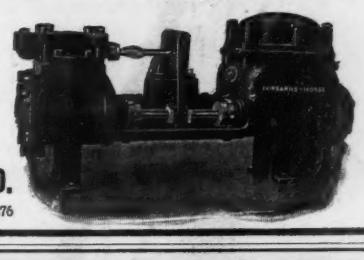

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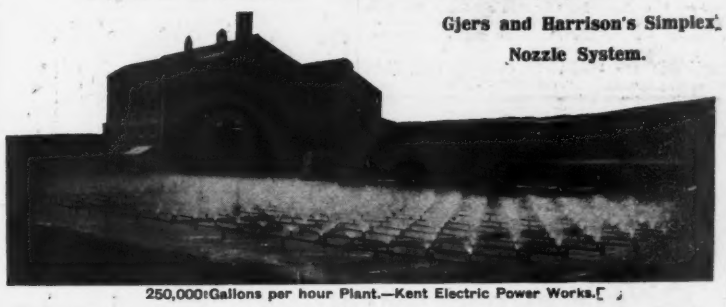

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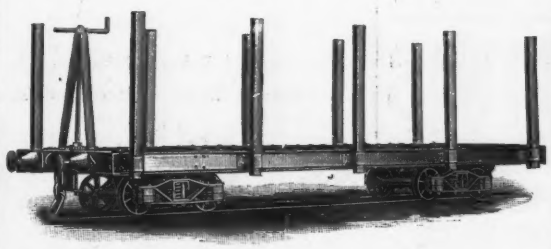

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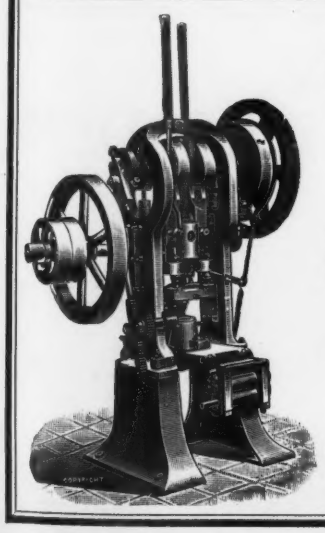

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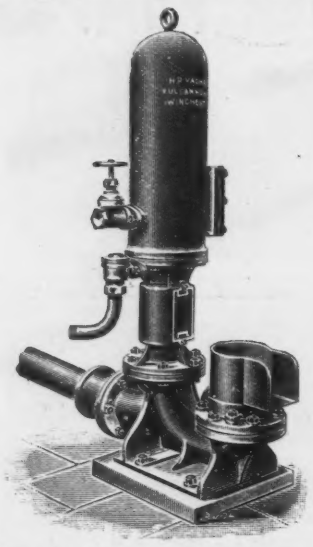

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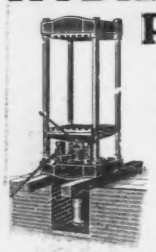

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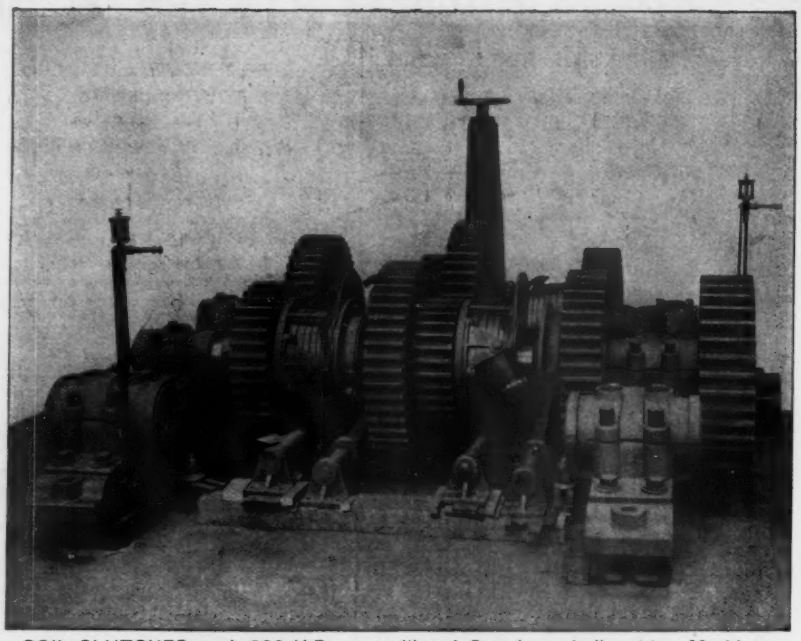

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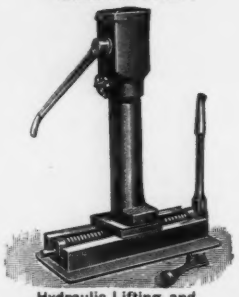

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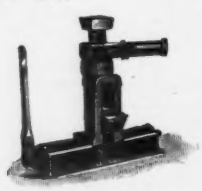

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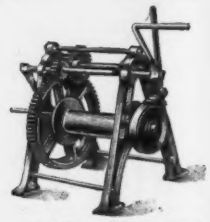

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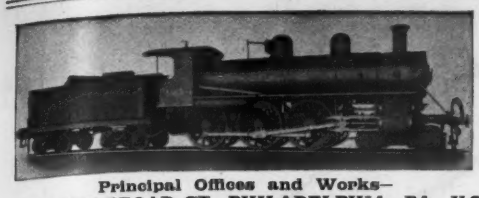

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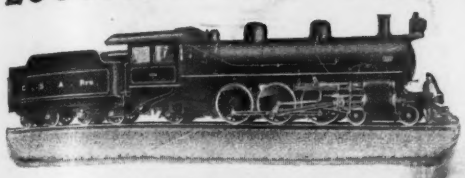

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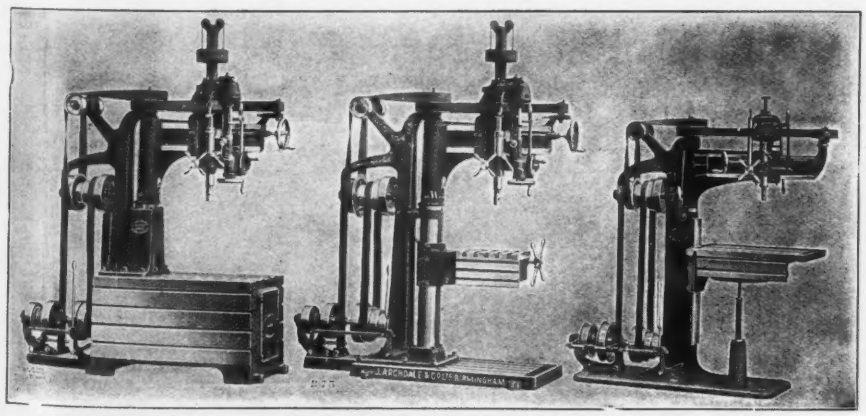

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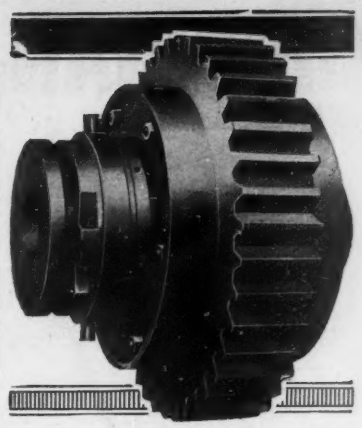

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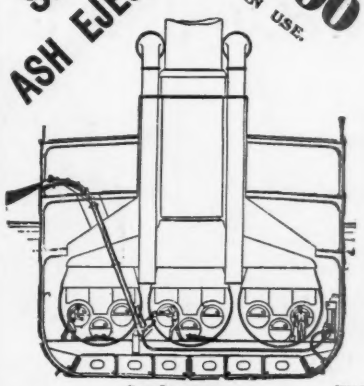

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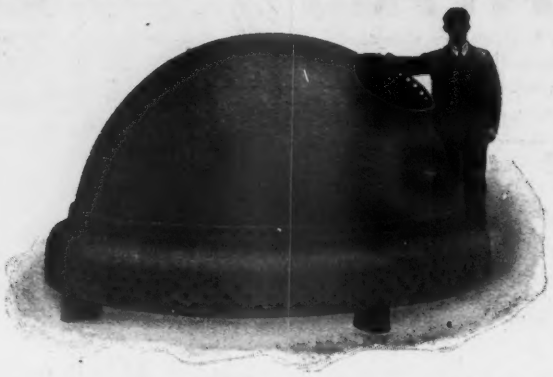

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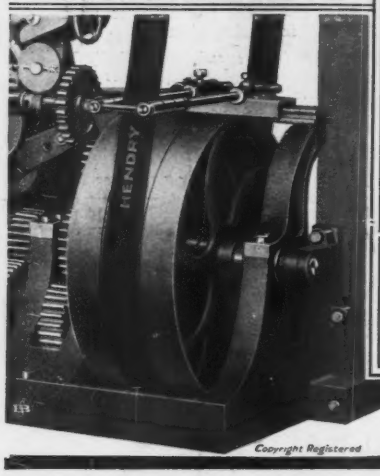

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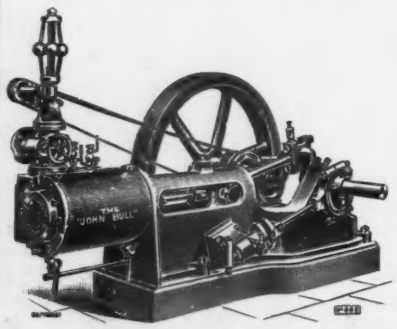

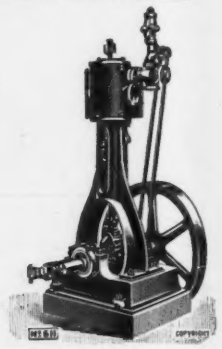

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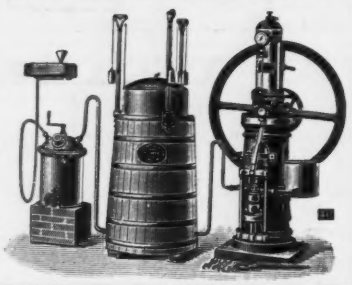

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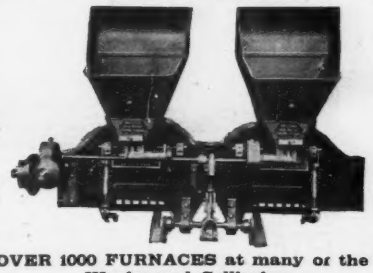

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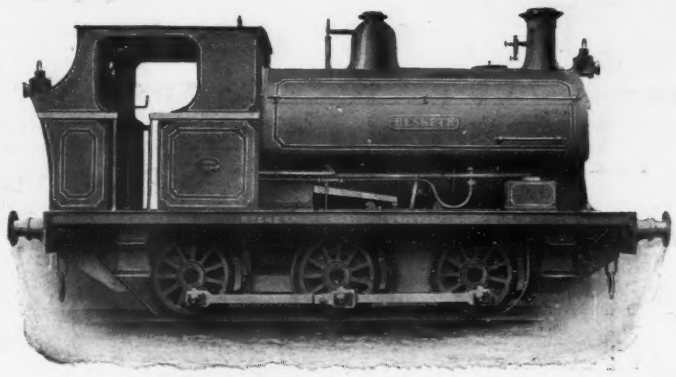

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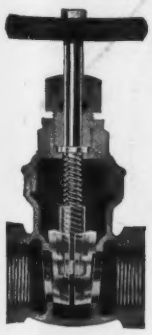

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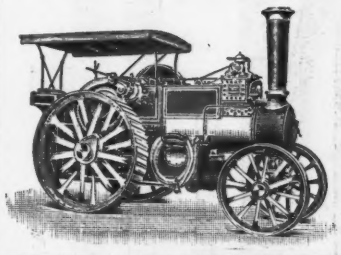

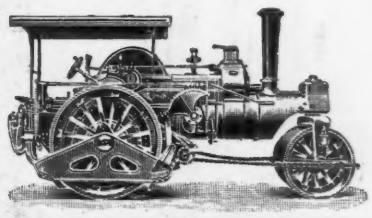

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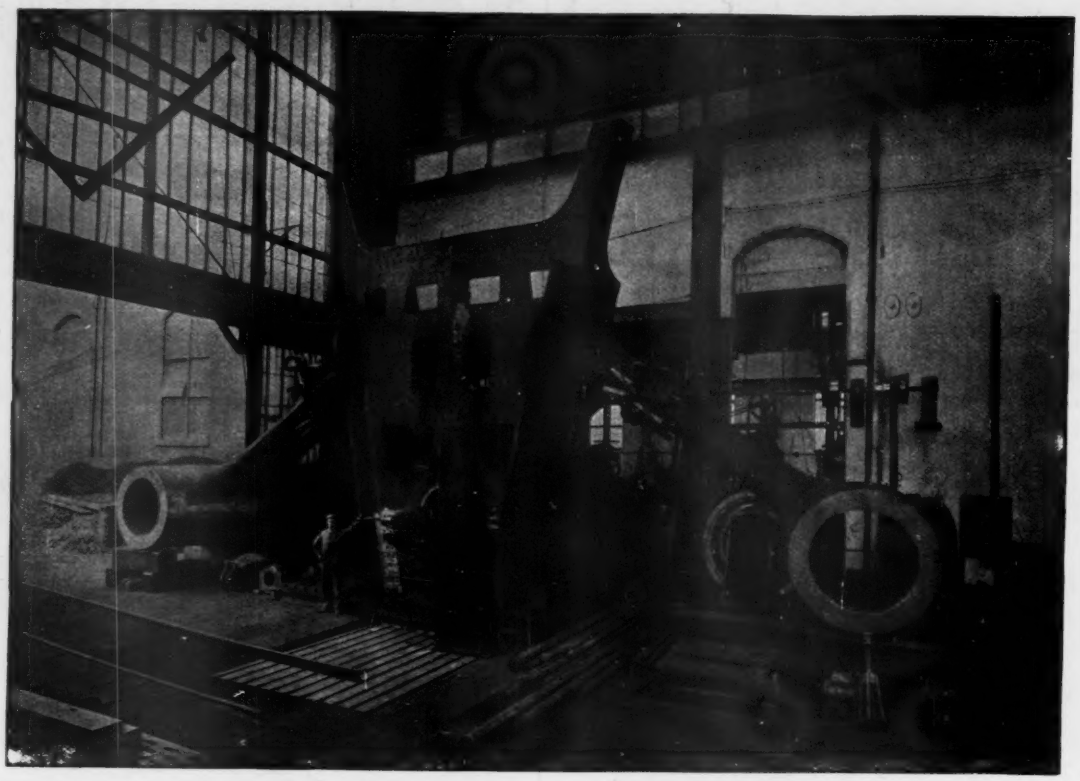

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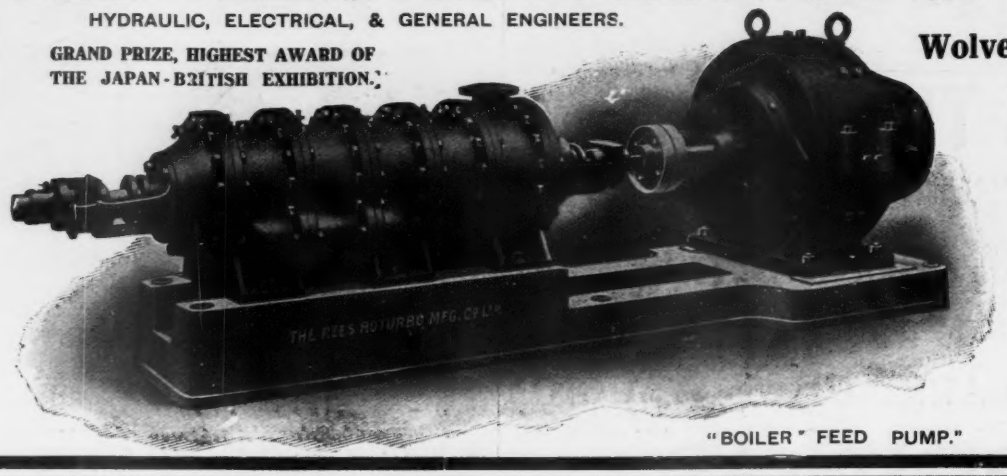

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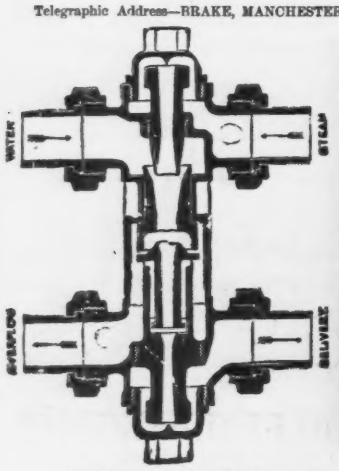

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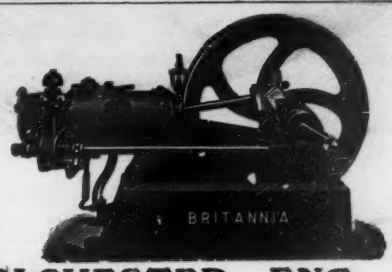

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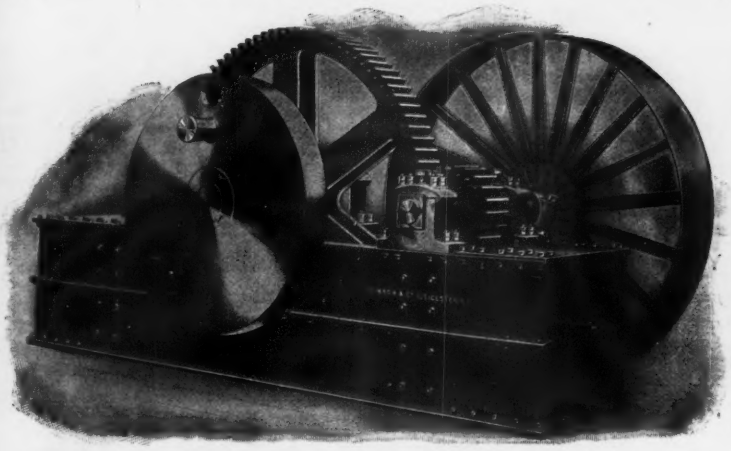

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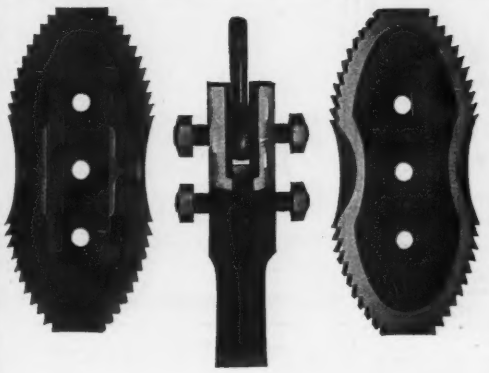

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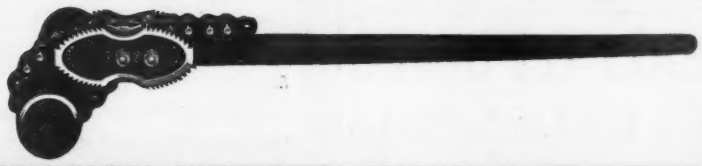

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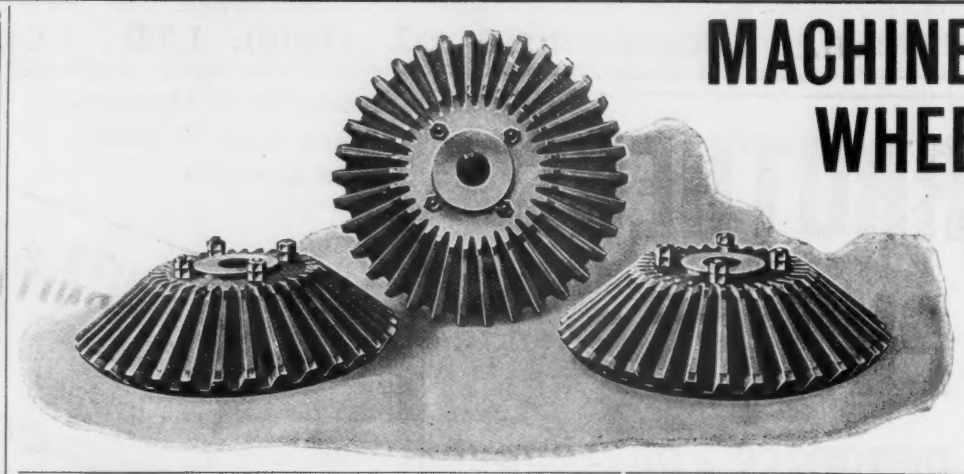

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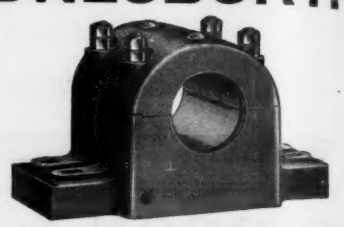

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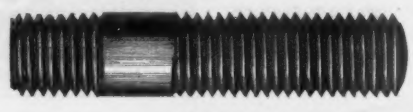

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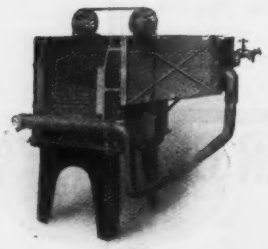

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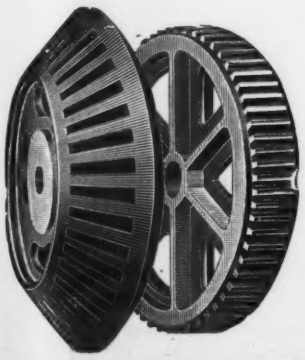

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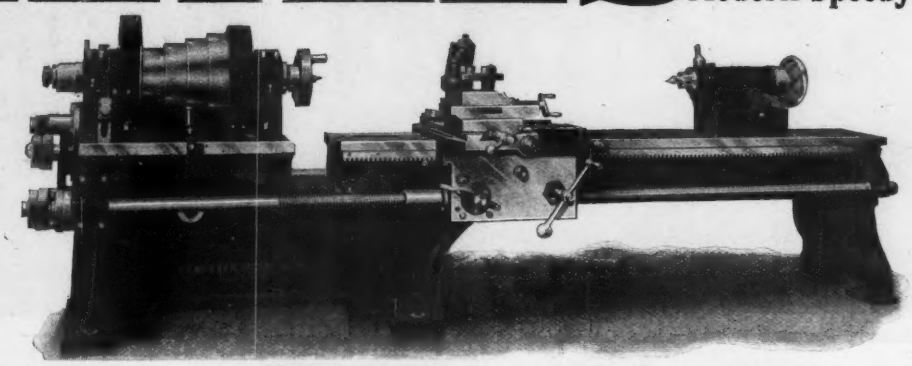

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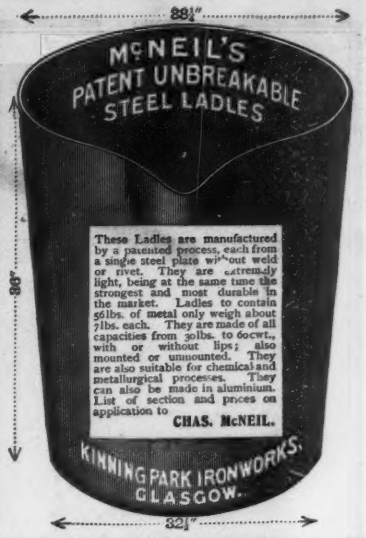
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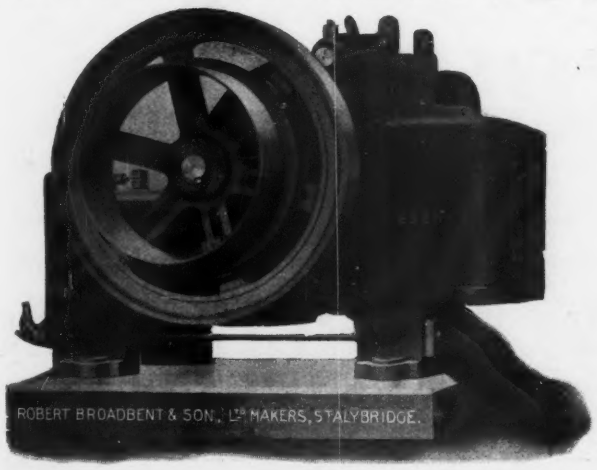

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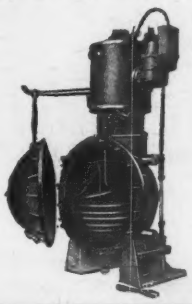

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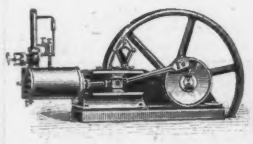

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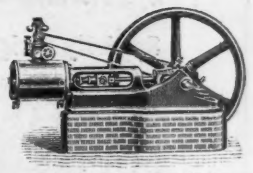

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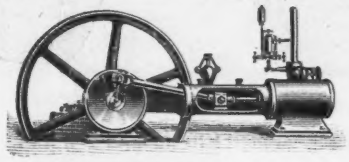

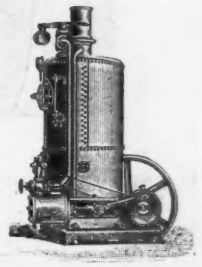

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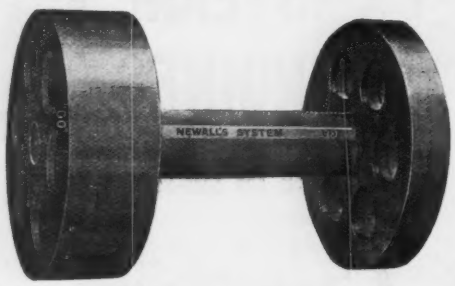

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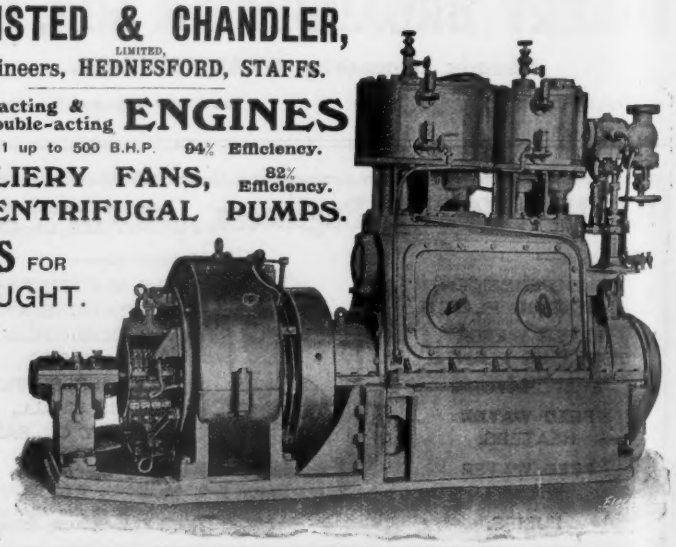

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